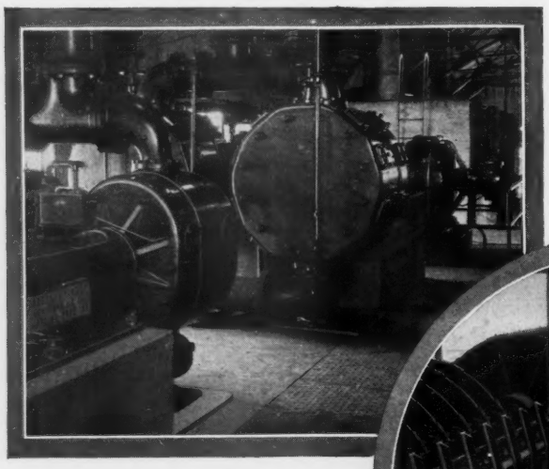
Compressed Air Magazine

Vol. 38, No. 12 London - New York - Paris December, 1933

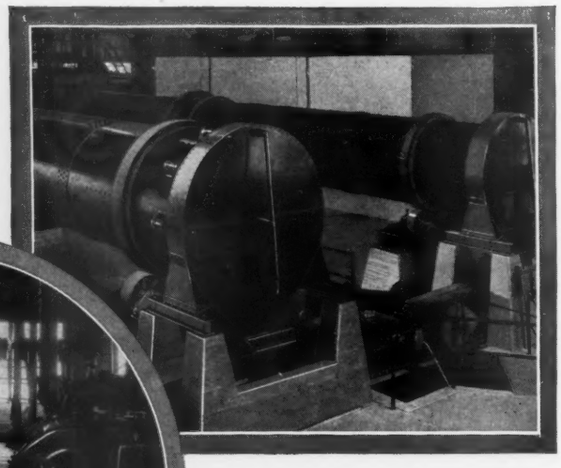
MALIGNE LAKE, JASPER NATIONAL PARK, CANADA

I-R Vacuum Pumps Help Houston Turn Waste into Profit



Two Ingersoll-Rand vacuum pumps which serve the two Oliver-United disk-type filters in the photo at the center.

Oliver-United filters which remove moisture in sludge received from an activated-sludge disposal plant.



Rotary driers which receive partially dried sludge from the filters and convert it into commercial fertilizer.

THE City of Houston, Texas, is producing revenue from the products of its municipal sewage-disposal plant.

The process now in use converts sewage into a first-class commercial fertilizer.

The sludge from an activated-sludge plant of usual design is treated with chlorinated copperas, and most of the moisture is removed on vacuum filters. It is then completely dried in rotary kilns. The whole process—from collecting the waste to loading the completed fertilizer in cars—takes less than 24 hours.

The four disk-type filters in use at the plant are served by two Ingersoll-Rand vacuum pumps, a Corliss-valve machine of 2,000 cubic feet per minute displacement, and a plate-valve machine of 4,705 cubic feet per minute displacement.

Ingersoll-Rand

11 Broadway
New York City

1057-C

As It Seems To Us

SAN FRANCISCO'S BRIDGES

TWO great bridges are taking form at San Francisco. Both are notable from an engineering and construction standpoint and will do much to consolidate the commercial and social interests of a populous area which has always had to rely heavily upon water craft for transportation of passengers and freight. One of these structures—an 8-mile causeway which will span the bay from San Francisco proper to Oakland—is the subject of an article in this issue. The other, on which construction is proceeding at a little slower pace, is being flung across the Golden Gate entrance to the harbor. It envisages a suspended roadway, 6,450 feet long, having a central span 4,200 feet in the clear, or 700 feet greater than the George Washington Bridge across the Hudson River.

A glance at the map of California will reveal the significance of these great works. San Francisco occupies the tip of a narrow peninsula, and is accessible by land only from the south. The bay, 50 miles long and part of one of the world's finest harbors, separates that city from Oakland, Alameda, Berkeley, and various other residential communities. Beyond them lie the two rich valleys, the Sacramento and the San Joaquin, with their important dairying and farming sections. Stretching out from these, and continuing eastward and northward, are the vast vineyards which merge into fine timberlands. Part of the lifeblood of San Francisco comes from these regions—the rest of it from the shipping that enters its harbor from the Seven Seas. The topography of the city, itself, is severe, and its climate is sometimes austere. Across the bay lie inviting, productive expanses where the winds lose their piercing darts and the fogs are turned back to the sea by a friendly sun. San Francisco can never move from its strategic location, however, so man is intervening to forge solid links of concrete and steel with the hinterland. The quickening tempo of the times has decreed that tugboats and ferries must give way to motor vehicles and rapid-transit lines.

Architecturally, these prodigious bridges will maintain the high standards which the Roeblings set when they linked Manhattan and Brooklyn and which mark the many fine spans erected since then in various parts of the nation. Structurally, they will match the world's finest.

Someone has computed that upwards of 50,000,000 man-hours of labor will be involved in making the required materials and putting them in place. Steel mills will be drawn upon for 287,000 tons of their products, and about a third as much concrete will be needed as for the Hoover Dam. The Transbay Bridge alone will consume 200,000 gallons of paint; and 30,000,000 board feet of lumber will be utilized in its construction, although no wood will remain as a permanent part of it.

OUR COVER PICTURE

COMPARATIVELY few of us ever see the high country in winter garb, but we all have an innate appreciation of its beauty. Our cover illustration is a camera study in the Canadian Rockies and is presented through the courtesy of the National Parks of Canada.

THE ASCENDANCY OF METALS

IF ONE were asked to explain in one sentence the essential difference between our present-day civilization and the more remote era when man was just emerging from savagery, as good an answer as any probably would be that we have learned to use metals. Copper, iron, steel, steel alloys are five words that connote volumes of history. They stand for power and light, for machinery and railroads, for bridges and buildings, for automobiles and ships, for telephones and printing presses. These metals have been paramount influences in our lives, habits, and attainments, though they have, of course, had valiant assistance from lead, zinc, tin, nickel, and others. To project the story of progress still farther ahead, we should have to add aluminum, magnesium, beryllium, radium, platinum, and a few more metals that are already potent factors but whose greatest power seems destined for the future.

It is a curious but interesting fact that as man has gone up the ladder of knowledge he has done most with the base metals. He has been able to toughen steel and to bend it to his needs, but he is still floundering around trying to learn how to handle gold and silver. The ancient potentates of Egypt and Babylonia wrought these metals into beautiful works of art, and they used them as the bases of monetary systems that apparently answered satisfactorily the needs of their commercial intercourse. Centuries later we are divided among ourselves, confused, and bewildered as to how to tie our currencies to these metals in such a manner that the moneys of the various countries will maintain a somewhat stable ratio to one another.

In the United States we are experiencing the astonishing anomaly of a nation "off the gold standard" but still revering gold. We have cut loose from gold temporarily, deprived ourselves of its steadying influence, but even by our forsaking it we have made ourselves more desirous of it. Its price, in terms of paper dollars, is mounting steadily, aided by governmental edict. Meanwhile, prohibition has been shifted from stimulating drink to stimulating metal, and gold has become contraband. Of our nation it must be said right now that we can handle our steel but not our gold.

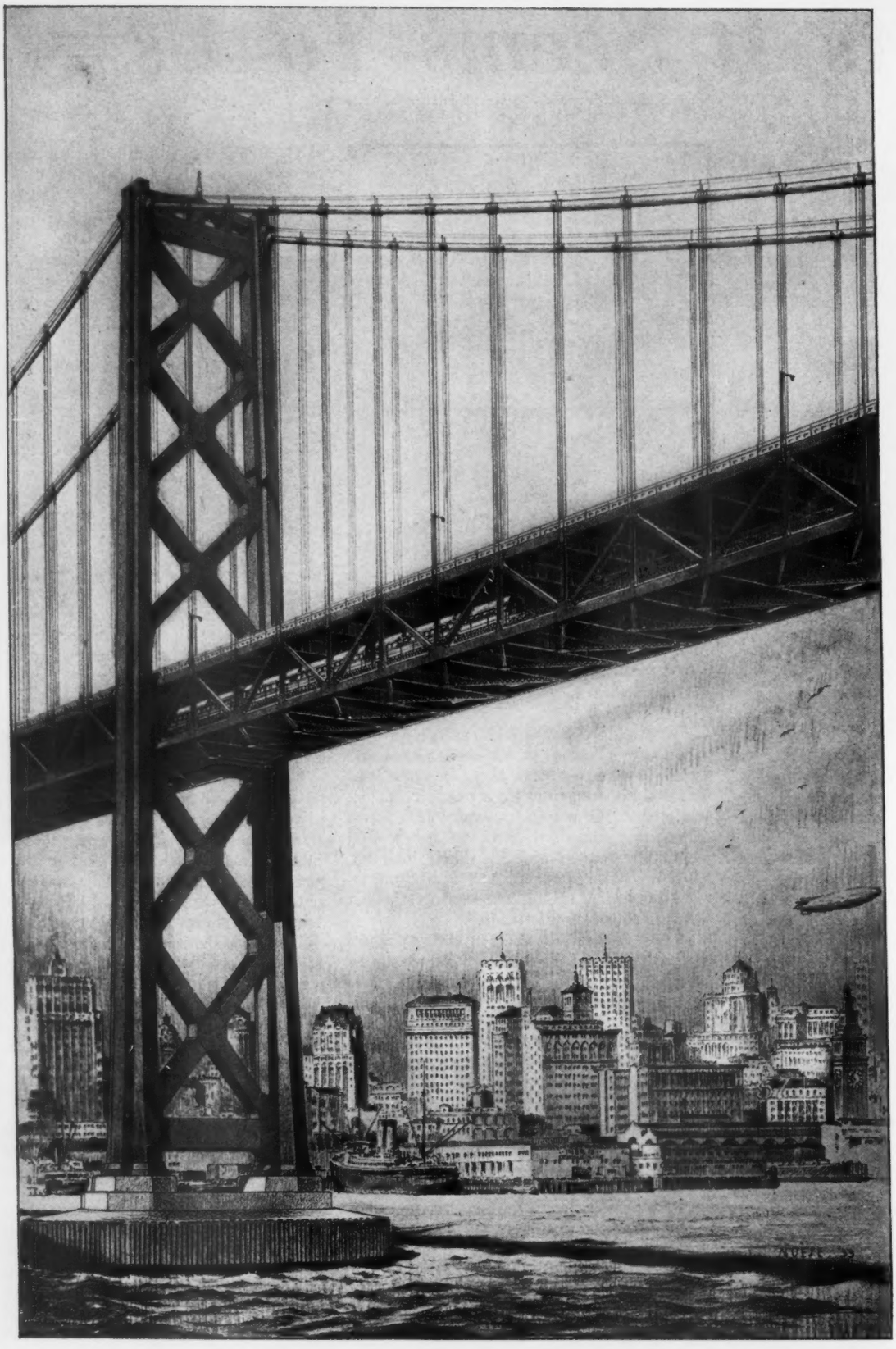
SAVING THE SOIL

ONE of the more interesting of the many forms of public works being set in motion by the Federal Government is that fostered by the Soil Erosion Service. Its purpose is to make a start towards curbing the wholesale denudation of our farm and grazing lands. It seems that while millions have been spent in helping agrarians to get more from the land, the land, itself, has been rapidly disappearing. Estimates have it that 35,000,000 acres which were formerly productive already have been rendered worthless for crop purposes and that 125,000,000 more acres are fast nearing impoverishment. The Mississippi River alone annually disgorges some 400,000,000 tons of suspended sediment into the Gulf of Mexico, not to mention the mineral matter which it carries in solution. All told, approximately 3,000,000,000 tons of soil material are washed from farm lands every year. The staggering volume that is involved can be more readily visualized when it is stated that 6,000 trucks loading at the rate of one a minute and working continuously would be required to move it.

The sum of $5,000,000 has been allotted to the Soil Erosion Service, and ten typical eroded areas have been selected for the initial program of restoration. To bring these tracts back to productivity it is necessary to repair the damage done and to set up means to prevent further washing away. The methods of doing these things will vary according to the conditions. Engineering will have its part, but agronomy and forestry will be even more important agencies.

The present methods of cultivating corn, cotton, tobacco, and other so-called free-till crops promote erosion, and it is planned to alternate these plants with strips of alfalfa, sorghum, and other dense crops which will arrest the activities of run-off water and retain the top soil. In grazing areas, the planting of grass, shrubs, and trees will be practiced, and the sections under restoration will be stocked with game with the expectation that land owners will eventually derive some income from them by giving sportsmen the privilege of hunting.

Experiments now underway on the Navajo Indian Reservation in New Mexico indicate that where overgrazing has led to the cutting of deep gulches in the surface. Nature can be made to do most of the work of repair. Shallow dams in these ordinarily dry *arroyos* will cause the run-off water following storms to deposit soil carried by it in suspension, thereby tending to build up these depressions to the general level of the surrounding country. The planting of grass and the prohibiting of grazing until it has gained a foothold will complete the rejuvenation of such areas.



THE BRIDGE
AND
SAN FRANCISCO

An artist-engineer's conception of a section of the suspension span, with the skyline of San Francisco framed beneath it. The tower, one of four, will be 465 feet high, and will rest on a concrete pier extending more than 200 feet below the water surface to rock. The two levels of the roadway will have a capacity of 30,000,000 vehicles a year, or about seven times the number now being ferried across the bay. Tolls equal to the present ferry charges are proposed at the outset, with gradual reductions over a period of twenty years. After that the crossing will be free.

Pacific Gas & Electric Company

PERSPECTIVE OF THE SAN FRANCISCO BAY AREA

This composite diagram shows the relationships between the various centers of population and indicates the important function that the bridge will fulfill. The structure described in this article appears at the center of the picture, and will have a total length of 8¼ miles made up of approaches, bridges, and a tunnel. The Golden Gate Bridge, on which construction has also been started, is shown at the lower left-center. It will be the largest suspension span so far built.

Bridging San Francisco Bay

LAWRENCE A. LUTHER

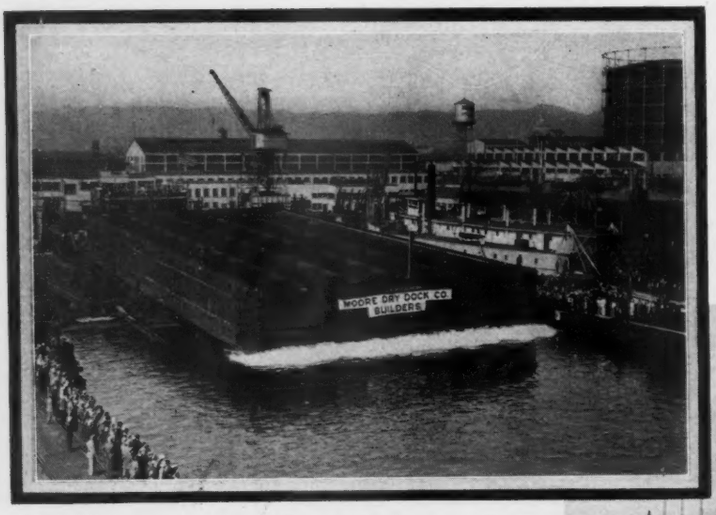
WHEN Senator Marconi expounds characteristics of his new short radio waves —tells us that radio echoes sometimes encircle the globe several times, and that a word covers its circumference in one-seventh of a second; and when our round-the-world flyers make their stupendous journey appear to be almost a week-end trip, then our earth loses in dimensions and begins to look like a small planet, indeed.

Less far-reaching but equally important in annihilating distance are bridges that span broad waterways and link smooth, spacious highways. These structures are supplanting ponderous ferryboats that have served so long in getting pedestrians and vehicular traffic from shore to shore. The region around San Francisco Bay is a case in point, and that explains the unprecedented bridge-building activity in that section of the Pacific Coast of late years. Three relatively new structures now span the tidal reaches of the San Joaquin and the Sacramento rivers: the Antioch Bridge, the fine railway bridge of the Southern Pacific Company at Martinez, and the 4-lane highway bridge across Carquinez Straits. In addition, a 6-mile-long, 3-lane, concrete causeway with a lift span extends from San Mateo to Hayward, on opposite sides of the bay. But these structures, big though they are, will be overshadowed by the two new bridges that are now under construction in that area—the Golden Gate Bridge, which will connect San Francisco with Marin County to the north, and the San Francisco-Oakland Bay Bridge which will link San Francisco with Alameda County lying to the east. In this article we shall concern ourselves only with the last-named structure, on which work is now well underway.

The City of Oakland, in Alameda County, has grown rapidly to a population totaling nearly 300,000 and, together with Berkeley, Alameda, and other smaller municipalities nearby, sends some 60,000 commuters across San Francisco Bay daily. This traffic is taken care of by ferries, a service that dates back, we are told, to 1851. The need of more adequate means of intercommunication between those populous centers has been recognized for years—in fact, as far back as the post gold-rush days Californians talked of bridging the bay at that point. The builders of the first transcontinental railroad even discussed the possibilities of a ferry mole terminating on Yerba Buena Island, which is the property of the Federal Government and will form a link in the San Francisco-Oakland Bay Bridge.

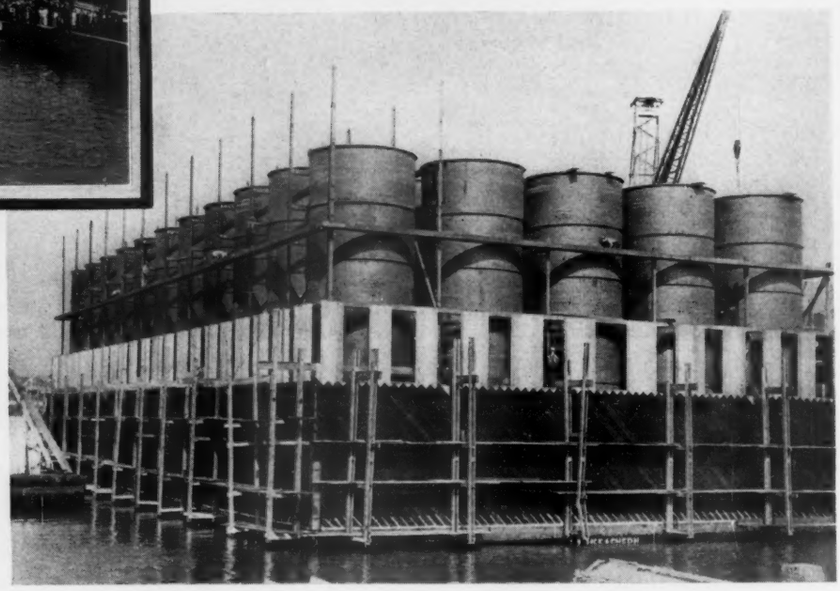
The automobile, more than any other factor, however, was responsible for the popular demand for a bridge to handle the ever-increasing volume of traffic that followed as a consequence. Soon after the turn of the century, the project began to receive more mature consideration, and several low-level bridges were proposed. But ranking officers of our navy refused to countenance any such design, and definitely opposed the construction of a bridge north of Hunters Point. Any possible restriction of the naval anchorage or of the fairway to the open sea by piers was promptly vetoed, even though adequate vertical clearance were assured. The idea of a bridge at Hunters Point for commuters was dismissed, after study, on the score that the investment would not prove economically sound on account of the long detours involved.

The situation, on the face of it, presented a number of serious obstacles. In March of 1928, after having suffered one defeat, a group of state legislators, San Francisco officials, and civic leaders, again besieged Congress. Pleas were made before the Committee on Interstate and Foreign Commerce; and local sentiment was fortified by the opinions of three engineers of national repute. The citing of 28 privately sponsored applications to the City of San Francisco for a permit to build a bridge doubtless served somewhat to carry conviction as to the popularity of the project



CAISSONS FOR WEST CHANNEL PIERS

Piers which will support the twin 2,310-foot suspension spans across the west channel from San Francisco to Yerba Buena (Goat) Island, will be constructed in open water with the aid of cellular caissons of a new type devised and patented by Daniel Moran. Each of these caissons will be made up of a number of vertical cylinders which will be capped airtight and filled with compressed air. Made buoyant in this way, the structure will be towed to its position for sinking, and the open spaces around the cylinders and within the outside walls filled with concrete. As the caisson is thus made to descend into the water, first its outside walls and then the cylinders will be built up 20 feet at a time. The cylinders will be heightened by cutting off the caps, welding on 20-foot sections, and then welding the caps back in place. By this procedure, the caisson will be



as well as to vindicate the claims made concerning its economic feasibility.

These local and state enthusiasts had kept their irons hot to strike since 1921, and probably would have had to wait much longer on Federal action had the interest of President Hoover not been enlisted at that juncture. Then the far from simple tasks of reconciling the conflicting demands of local bridge proponents and of naval chiefs and of selecting the site for the structure were assigned to a group of nine men appointed jointly by President Hoover and Governor Young. This body was known as the Hoover-Young San Francisco Bay Bridge Commission, and included representatives of the army and the navy.

This commission first met in the office of Governor Young on October 7, 1929, and an extract from a resolution then adopted clearly explains the task that was ahead of it. To quote: "To work out a solution of the State and interurban traffic needs between the counties of San Francisco and Alameda across San Francisco Bay, reconciling these with the needs of national defense and the national interests of navigation." The State Department of Public Works was asked to make engineering, economic, and traffic surveys with a view to determining the relative value and practicability of the five bridge routes under consideration. The centers of population and the trend of the latter in the several cities affected were carefully charted, and analyses were made of the interurban and through traffic. In this work of plotting incidence of population and of land and water traffic, the data that had been compiled from time to time by the earlier bridge promoters proved of invaluable aid. Information regarding earthquake faults was procured from the Southern Pacific Company and from other sources; and the calculations made have been based on data covering structural resistance to seismic forces as determined in this country and in Japan. The City of San Francisco appropriated $40,000 to defray the cost of exploratory borings. With the exception of some core drilling with diamond drills, this was done with high-pressure water jets.

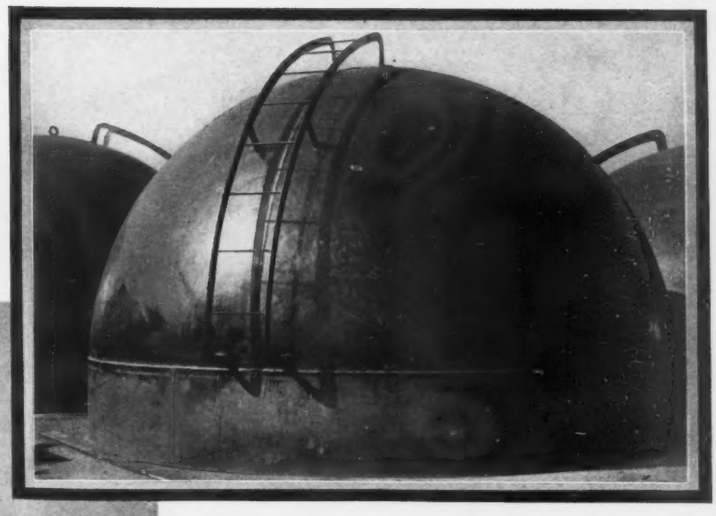
Early in August of 1930 the Hoover-Young Commission made a report to the effect that the bridge was necessary to the development of the area, and that the project was structurally and financially feasible. The general location and the alignment of the structure as finally decided upon were also recommended by the board. As an accompanying map shows, the bridge will extend from Rincon Hill in San Francisco to Yerba Buena Island, which divides the bay at that point into a west and an east channel, or bay. From there it will continue on to Oakland. From end to end the structure will be 8¼ miles long; and, briefly, will involve the building of a west-bay crossing, a tunnel, and an east-bay crossing.

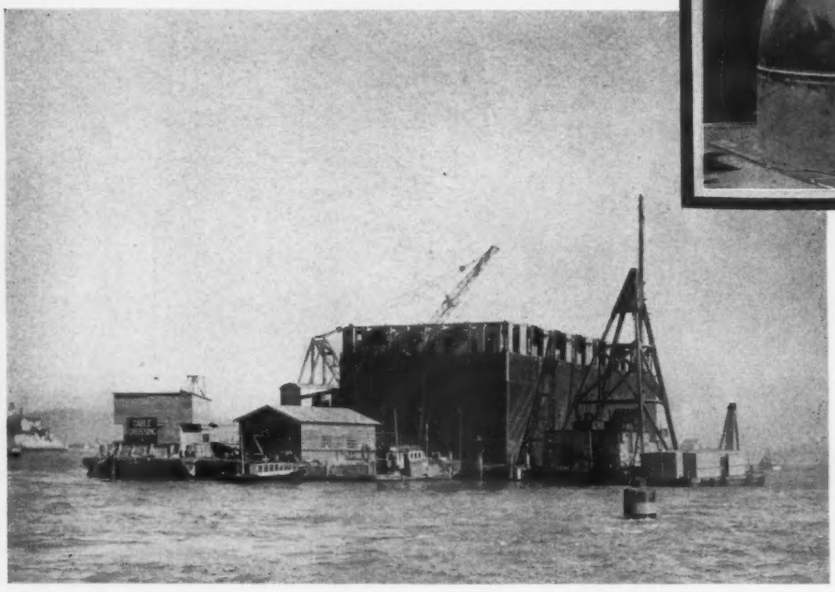
The west-channel crossing between San Francisco and the island will be of the double-deck suspension type and will consist of two main spans, each 2,310 feet long, and of four 1,160-foot side spans. It will be connected with the San Francisco anchorage by three deck-truss spans having a total length of 863 feet. The structure will be supported mainly by four tower piers and three anchorages: the shore anchorages and a central anchorage, to which latter the 28-inch-diameter cables from the suspension spans will also be secured. The steel towers vary in height—the outer two rising to elevation 465 and the inner two to elevation 505, and will give the bridge a vertical clearance at high water ranging from 180 to 214 feet. The upper deck will have a 58-foot roadway with six traffic lanes for automobiles and light trucks, while the lower deck will have a 31-foot, 3-lane roadway for heavy trucks, as well as two tracks for interurban cars.

Before the design for the west-bay crossing was decided upon, a series of model tests of different types of bridges was conducted in the Engineering Materials Laboratory of the University of California under the direction of George E. Beggs, Raymond E. Davis, and Harmer Davis, and in collaboration with the engineering staff on the project. Studies of cantilever types, of a single suspension span covering approximately half the crossing, and of two main suspension spans with a common central anchorage to bridge the entire west channel resulted in the choice of the latter. In making the selection, the main considerations were cost, weight and carrying capacity, and immunity to earthquake shocks. The bridge now building will, it is estimated, have nearly twice the margin of safety ordinarily found in new structures in the bay area.

On Yerba Buena Island the traffic will be carried first through a double-deck tunnel 540 feet long, 80 feet wide, and 60 feet high, and then over a 1,145-foot, double-deck concrete viaduct. This brings us to the east-bay crossing, which is of the cantilever type. Its main span will be 1,400 feet long and provides a clearance at high water of 185 feet. Interposed between the viaduct and the west anchor arm of the cantilever will be four 219-foot deck-truss spans, while five through truss spans, with an average length of 51 feet, and fourteen deck-truss spans, averaging 291 feet in length, will connect the east anchor arm with a fill on the Oakland shore. Plans have been worked out but not yet prepared for the San Francisco and Oakland approaches and for the interurban-railway facilities.

progressively built up and sunk until its cutting edges come to rest on the bottom, from 70 to 105 feet below the water surface. The caps will then be removed from the cylinders so that they will be open wells through which the bottom material will be dredged with 2-cubic-yard clamshell buckets. In this manner the caisson will be further sunk until it reaches rock, after which concrete will be poured into the cylinders. This type of caisson eliminates the need of men working in high-pressure air. The view on the extreme left shows the launching of the substructure of the caisson for the central anchorage. Next to it is the same caisson as it appeared after the first 20-foot section had been added to its 55 cylinders. Below, on this page, is shown the caisson for Pier 4 moored in position by anchors and being made ready for sinking. At the right is a close view of one of the cylinder caps.





Work on the substructure of the San Francisco-Oakland Bay Bridge is now well in hand; and, in order to avoid confusion in describing this phase of the operations, let us take up each of the several contracts in turn, beginning at Rincon Hill. Healy-Tibbitts Construction Company, of San Francisco, was the successful bidder on the $1,036,500 contract which includes the San Francisco anchorage, five 65-foot reinforced-concrete girder spans between Rincon Hill and the anchorage, and piers A, B, and 1. These piers will support the steel approach spans between the anchorage and the main crossing. A delivery track has been run by the contractor to the anchorage site, where facilities have been provided for producing the concrete required on this job.

The anchorage is to be a huge monolith containing 68,000 cubic yards of concrete into which will be embedded the steel grillages and eyebars for attaching the suspension cables. It will have a maximum height of 160 feet, and will be 108 feet wide and 184 feet 6 inches long. A total of 24,100 cubic yards of earth and rock have been excavated with steam shovels, hauled away by truck, and wasted. Concrete is mixed and batched by an electrically controlled, automatic machine of the Davis type with Toledo scale equipment turning out 2-cubic-yard batches, and is placed by a 4-cubic-yard bottom-dump bucket handled by a 30-ton derrick with a 115-foot boom. Wood forms are employed, and the concrete is cast sectionally in interlocking blocks to give maximum resistance to shear. Pneumatic vibrators, taking air from a Type 20 portable compressor, are used after the application of each batch to consolidate the concrete. The officers of the Healy-Tibbitts Construction Company are: Charles H. Horton, president; J. H. Edwards, secretary; C. T. Morton, chief engineer; and Martin E. Brown, general superintendent. N. W. Reese is resident engineer on this contract for the state.

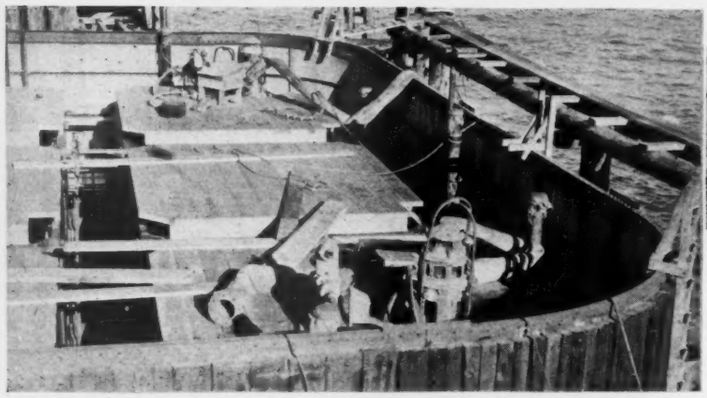
The west-channel contract covers the four tower piers—numbered 2, 3, 5, and 6—and the central anchorage, or Pier 4. This contract is held on a bid of $6,957,100 by the Transbay Construction Company, an affiliation of five western contracting firms, as follows: MacDonald & Kahn, San Francisco; J. F. Shea Company, Portland; General Construction Company, Seattle; Pacific Bridge Company, San Francisco; and Morrison-Knudsen Company, Boise. Charles F. Swigert is president of the Transbay Construction Company; J. A. McEachern, vice-president; Charles A. Shea, secretary; Felix Kahn, treasurer; C. P. Dunn, chief engineer; and Ben Cook, construction superintendent. The resident engineer for the state on this contract is I. O. Jahlstrom.

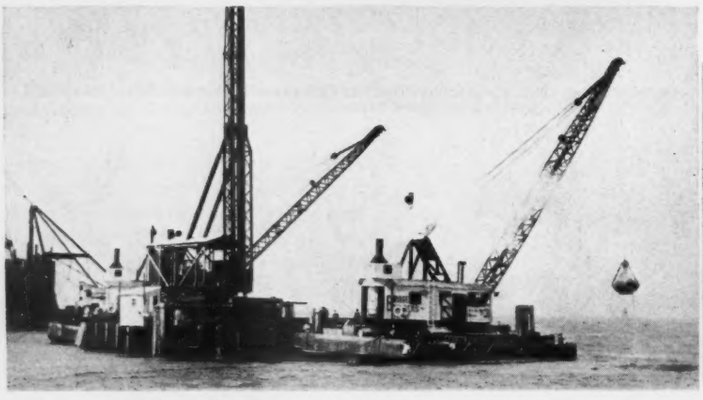
Pier No. 2, just off San Francisco's pierhead line, is nearing completion. It is 52x122 feet in plan, and is being built within a cofferdam of steel sheet piling driven around a floating timber crib. Two 30-ton derricks, each with a 120-foot boom, were used in excavating the material, which is being handled by 3½-cubic-yard clamshell buckets. Rock was encountered at a depth of 100 feet, and pumps and jetting equipment were employed in cleaning up preparatory to placing the concrete seal. All told, 19,000 cubic yards of concrete was placed with 4-cubic-yard bottom-dump buckets. From elevation —10 to the tower seat, at elevation +40, reinforced-concrete is being poured, in the dry, in 6- to 12-foot lifts using timber forms.

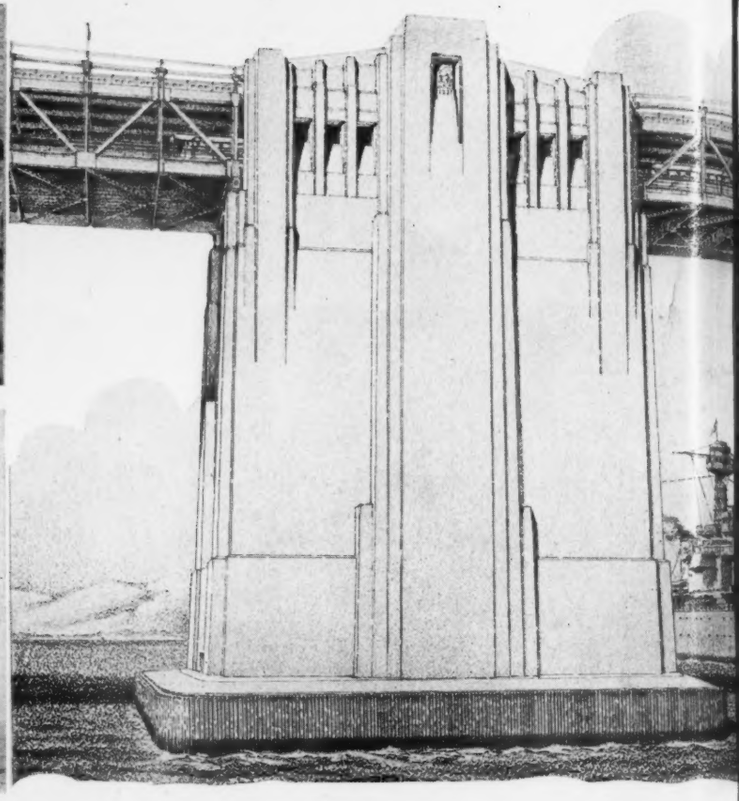
Piers 3 and 6 will each be 74½x127 feet in plan; Pier 4 will be 92x197 feet in plan and rise 300 feet above low water; and Pier 5 will be 57x127 feet in plan. Like Pier 2, they are to top at elevation +40. The caissons for the deep-water piers are calculated to come to rest on rock between the following elevations: Pier three, —211 and —225; Pier four, —180 and —200; Pier five, —94 and —100; and Pier six, —175 and —183. Only a nominal amount of rock excavating will probably have to be done before placing the seals on these footings.

At this writing the caissons for piers 3, 4, and 5 are under construction, while the caisson for Pier 6 has been towed to its location. The contractor is doing all the dredging and the structural operations on the latter pier from a floating base augmented by a heavy, laminated-timber fender and working platform that has been built around the caisson. The clearance between the fender and the caisson walls amounts to 7 feet. As the conditions at Pier 5 will be much like those at Pier 6, similar platforms will be used there.

Fixed working platforms, with special foundations for 30-ton derricks, have been provided for piers 3 and 4. Their construction in 70 feet of water, subject to swift tidal movement and to disturbance caused by passing shipping, was a big task, in itself. The platforms rest on 120- to 130-foot piles driven to a depth of 40 feet; but the heavy derricks—four in the case of the big central anchorage and two in the case of Pier 3—rest on groups of cylinders and piles. Eight-foot-diameter cylinders were used; built up to a length of 120 feet; and given a penetration of about 20 feet by interior dredging with a small clamshell bucket. Five 125-foot timber piles were then driven inside by the use of a follower, and the cylinder filled with concrete placed wet. Three such piers, placed on an average 50 feet apart in triangular formation, support one derrick. Bracing is effected by 24x24-inch wood struts,







PIERS FOR EAST-BAY CROSSING

Twenty-one piers will be required for the Yerba Buena Island-Oakland section. Four of them will be in deep water and will be built up within cellular caissons. The top picture shows a corner of one of these caissons. It is 60x90 feet, with the steel cutting edges built up approximately 13 feet high. It contains fifteen square cells, arranged in three rows of five each. These cells are not fitted with cylinders as those in the compressed-air caisson, but the bottom of each cell is timbered over and made airtight. The walls and cells are built up, and concrete is poured around the cells, this process being continued until the caisson is landed on the bottom. The timbers at the bottoms of the cells are then jerked free with derricks and rise to the surface with the water. Excavating is carried on through the cells with clamshell buckets. To facilitate sinking, the cutting edges are fitted with both air and water jets. The bottom picture shows dredging for one of the shallow-water piers, which will be excavated inside cofferdams.

while cables tie the piers and intervening cylinders and wood piling together.

To the engineer, the pier caissons and their method of sinking are probably the most interesting features of this project, which is distinctive not only because of the breadth of the span and its vertical and horizontal clearances but also because of the depth to which the piers must be carried to give them a firm footing. As the caissons vary only in size and not in design, a description of the construction and lowering of one of them will suffice.

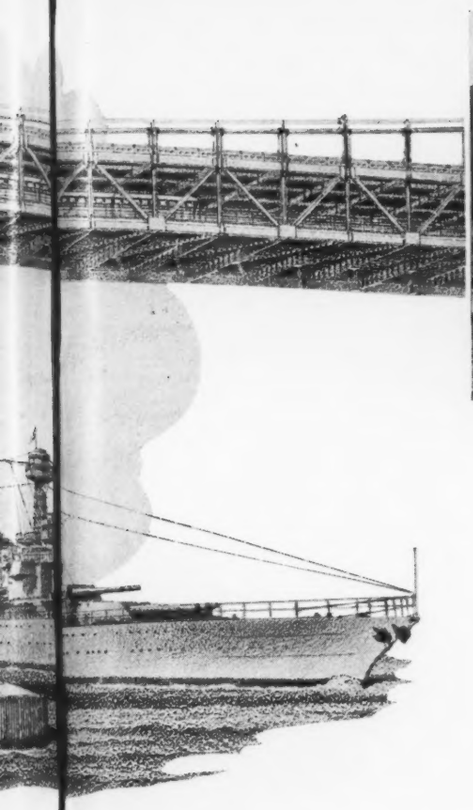
In the yards of the Moore Drydock Company, in Oakland, the cutting edges of the cellular, reinforced-concrete caissons are laid down much as are the keels of ships. The lowermost section of each caisson is mounted on top of the cutting edges on shore; is from 13½ to 17½ feet high, depending upon the ultimate size; and is of all-steel construction. This unit is then launched, as follows: Greased skids are inserted at four points between the cutting edges and the building ways; bags of sand are placed at intervals below the cutting edges; and the building blocks are knocked out from under, thus permitting the structure to settle on the sandbags. At a signal, men puncture the bags and, as the sand runs out, the caisson settles on the launching ways. A tug gives a light jerk with a towline, and down it slides into the water.

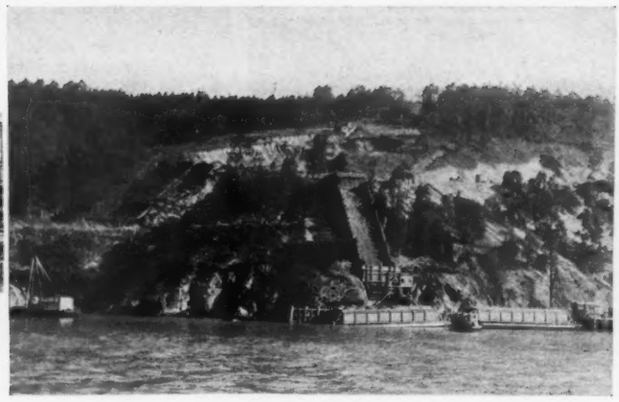
Moored where it can be served conveniently by cranes and other shipyard facilities, the caisson is now built up with timbered walls on a heavy steel framework to a height of from 73½ to 77½ feet, which is required for the beginning of sinking operations. This rigid bottom construction is necessary so as to reinforce the cutting edges and to prevent caissons from being severely sprung as the result of uneven bearings on obstructions or hard strata. Before a caisson is towed to its working site by five seagoing tugs it is ballasted with about 800 cubic yards of concrete placed by Rex Pumpcrete machines.

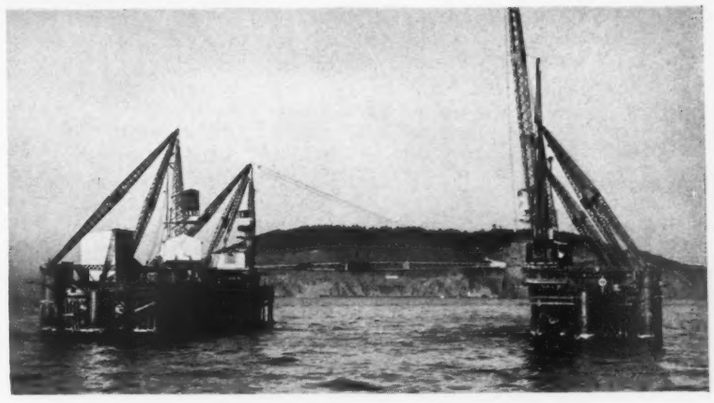
The cutting edges extend 6 inches below the 14-inch bearing surface carried inward from the outer wall plates to the diagonal inner walls which give entrance to the cellular lower part of the transverse and longitudinal construction used. The inner structural steelwork consists of plates, suitably braced, and is arranged to serve as forms for intersecting concrete walls, spaced 15 feet apart, with 42-inch walls lying just inside the outer plates and filling the tapered structural-steel assembly directly above the cutting edges. The space between the cutting-edge elevation and the lower face of the interior bracing—the area which would serve as a working chamber in a pneumatic caisson—is about 5 feet high. Both the upper and lower faces of the intersecting bracing somewhat resemble huge honeycombs with square cells. Subsequent to launching, there is welded over each of these cells a transition cone 15 feet square at the bottom and terminating in a 15-foot-diameter ring at the top. These serve as bases for the nest of dredging wells through which the excavating is done.

The 92x197-foot caisson for the central anchorage contains 55 of these dredging wells arranged in five parallel rows of eleven each. In the smaller caissons there are but 28 in four rows of seven each. The wells are 15 feet in diameter; made of 5/16-inch plate; welded to give airtight construction; and capped with domes provided with air connections. This capping is done before the caissons leave their moorings at the yard. Between each row of wells are longitudinal and transverse 8-inch I-beam struts with K-bracing. These engage 21-inch I-beam wales to which 10x12-inch planking is bolted vertically — the spacing being calculated in accordance with the maximum hydrostatic head which various wall areas will have to withstand in the sinking process. Creosoted 4x10-inch sheeting is spiked on diagonally and caulked with oakum.

Nothing short of a visit to a caisson during the sinking process can give an idea of the stresses to which it is subjected by tidal currents and by heavy wave action during rough weather. A maximum current of four knots for ebb tides at the site of Pier 6 is considerably less than that of six knots which complicates the building of the San Francisco tower pier







CENTRAL ANCHORAGE AND WORKING SCENES

The sketch occupying the central portion of these two pages shows the central anchorage to which the cables of the tandem suspension spans will be made fast. This concrete support will rise 301.5 feet above the water and will rest upon a 92x197-foot pier extending nearly 200 feet downward to a firm footing.

Between the two bridge sections the roadway will consist of a tunnel through Yerba Buena Island. This bore will be excavated 81 feet wide and 56 feet high. Before it is driven, overlying rock for 200 feet in from one portal will be grouted to increase its stability. At the top is a view showing the chute down which spoils pass to a belt conveyor for loading on to barges.

Eight-foot steel cylinders 120 feet long and wooden piles up to 125 feet long were sunk through 70 feet of water and then 40 feet into the bed of the bay to provide foundations for the 30-ton derricks which will be required for building the central anchorage pier. Two fixed working platforms, of which these foundations are a part, are shown here with their equipment.

of the Golden Gate Bridge. But the San Francisco-Oakland Bay Bridge caissons are being sunk without the auxiliary cofferdams employed in the case of the former.

The caisson for Pier 6 is held in position by 22 spring lines radiating to as many reinforced-concrete anchors each weighing 25 tons and lowered at a point about 350 feet away. A novel feature of these anchors is a piping system which permits jetting them down some 20 feet into the mud.

Compressor plants with standby units will serve all caissons, and air at 3½ pounds pressure is being delivered to the capped wells through 2-inch lines tapping manifolds. These wells act, in effect, like so many pneumatic jacks and, being independent of one another, assure considerable flexibility of control. By making it possible somewhat to compensate for irregularities in the surface underlying the cutting edges they tend to minimize the danger of a caisson tipping during the early stages of the dredging operations, and by quickly increasing or lowering a caisson's buoyancy give it a large measure of stability during all stages of the sinking.

As each caisson gradually descends, it is built up section by section and the spaces outside of and in between the dredging wells are filled with concrete. In the case of the cylindrical wells it is necessary to remove the domes before the 20-foot lengths can be added. After the cylinders have been extended they are again capped until the caisson has reached a certain depth, when they all remain open for dredging. Only a few of the wells are used for excavating at the beginning of the dredging operations. Bottom-dump buckets will be employed for the placing of the seals.

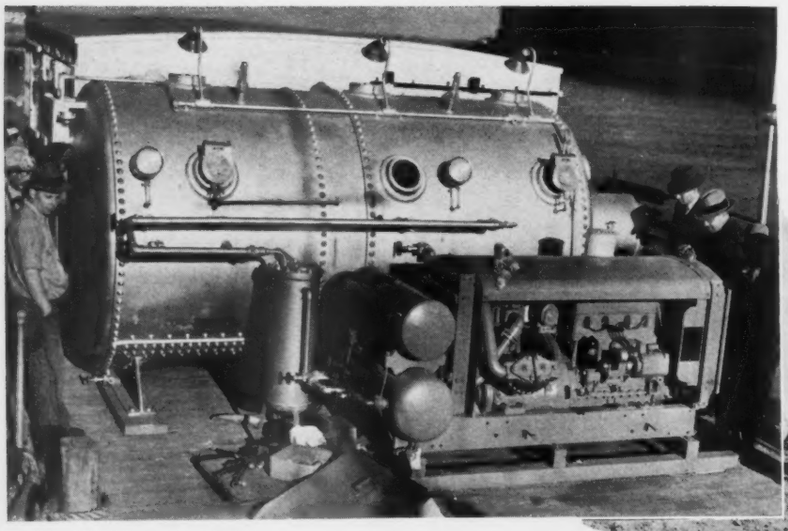
The next contract, that for the Yerba Buena Island work, involves an expenditure of $1,821,293. It includes the suspension-span anchorage and cable tunnels, the double-deck tunnel and viaduct, the substructure of the deck-truss spans leading to the east-channel crossing, Pier E1 that will support the west anchor arm of the cantilever, and approach roads. This was awarded to the Clinton Construction Company, of San Francisco, of which W. B. Brinker is president; A. Huber, vice-president; and A. Petersen, construction superintendent. Tom Conolly is in charge of the tunnel operations, and H. Carter is resident engineer for the state.

Steam shovels have begun excavating on the west approach to the tunnel and on the necessary construction roads. Spoils are disposed of quickly on this job. They are dumped from trucks, on a timber platform, into an inclined chute that loads the material on to a belt conveyor which carries it to dump barges.

The next and last contract represents an expenditure of $4,495,854, and is for the substructure of the east-bay crossing. It is held by Bridge Builders, Inc., an affiliation of Bechtel-Kaiser-Warren Company, Raymond Concrete Pile Corporation, Dravo Contracting Company, Missouri Valley Bridge & Iron Works, and the Utah Construction Company, with Henry J. Kaiser, president; M. M. Upson, vice-president; L. S. Corey, secretary; E. H. Connor, managing engineer; C. B. Jansen, general superintendent; and W. E. Waste, office manager. V. A. Endersby is resident engineer for the state on this job.

This part of the project involves the construction of 21 piers—four of which are deep-water piers, numbered E2 to E22, inclusive. Pier E2 will be built inside an open cofferdam. It will be 41x120 feet in plan; is to find a footing on rock at —40; and to top at elevation +40. Rock at the sites of piers E3, E4, and E5 lies at an average depth of 300 feet; but the contract specifies that the first one be carried to elevation —230 and the two others to —170. The excavations for these three piers are to be dredged through open wells in circular reinforced-concrete caissons.

So far, caisson for Pier E3 is under construction. It is 80x134½ feet in plan and will top at elevation +40. Caissons for piers E4 and E5, which are 60x90 feet and 4¾ inches in plan, have been placed and are to top at elevation +30. The latter has penetrated mud and



MEDICAL LOCK

This medical lock (left) is maintained for recompressing victims of compressed-air illness or "bends." Beside it is the 2-stage, air-cooled portable compressor which supplies it with air.

A huge concrete block of 68,000 cubic yards will provide an anchorage for the suspension span cables in San Francisco. All concrete is being consolidated with pneumatic vibrators (below).

the dredging has started. To facilitate these operations, two working platforms are provided, one on either side of the respective pier sites. Each is 5,250 feet square and is supported by heavily braced timber piling. It carries a 30-ton derrick with a 100-foot boom, and compressor and other equipment.

The structural-steel cutting edges for these caissons are also constructed in the yard of the Moore Drydock Company. In this case, however, they are not built up before launching and towing, as are those for the west-bay crossing. After reaching the scene of operations, exterior walls in the form of sectional cofferdams are set up on the cutting-edge sections. These are made up in the materials yard of Bridge Builders, Inc., and consist of 12-foot lengths of 4x10-inch untreated fir planking assembled vertically and bolted at the ends to 10-inch steel channels—3x4-inch angle iron serving as intermediate bracing. Joints between planks are caulked in the yard. These cofferdams are permanent at all sites where there is wave action—temporary wooden forms being used above the water line.

KEEPING IN TOUCH

Communication between the widespread parts of the work and between the job and shore offices is carried on by means of a radiotelephone system. The man shown here is in the office of one of the contractors.

Steel forms are employed for pouring the 4-foot-thick outer walls and the 3½-foot transverse and longitudinal inner walls that divide up the area into 28 rectangular dredging wells. These forms are in sections and hinged to facilitate setting up after each 12-foot lift. Three-cubic-yard buckets are used to place the concrete. The cellular construction of the caissons materially reduces the piers' ratio of imposed load to bearing surface, and was chosen because of the condition of the bottom in the east channel.

For dredging, the cutting edges are supplied with water by sixteen 6-inch lines and with air by six 3-inch lines. These serve 76 water jets along the cutting edges and 124 air jets. Part of the latter discharge from points 17½ feet above the cutting edges and part from points 30 feet higher. These side-wall jets have to be built up with the concrete walls. Upon reaching the prescribed depths, the footings will be inspected by divers and seals poured to a height of 20 feet with bottom-dump buckets.

Work has also been started on piers E19 to E22, inclusive, on the Oakland side of the bay. Pier E19 is 48x108 feet in plan, while the three others are 44x108 feet. Top elevations range from +45.25 for Pier E19 to +29.25 for Pier E22. Cofferdams of 72-foot interlocking sheet piling, with a 36-inch I-beam girder attached to each fourth section, are driven around steel wales supported by timber piling and timber struts. Floating whirler derricks excavate to elevation —50 with 2-cubic-yard buckets, and 50- to 80-foot timber piles are driven on 4-foot centers within the cofferdams with track-mounted gantry drivers whose transverse rails for moving the working track are carried on the ends of the 36-inch I-beams. A 5-foot gravel blanket is laid before the excavations are sealed with 2,700 cubic yards of concrete. The remainder of the concrete is poured in the dry after the cofferdams are dewatered.

An interesting departure on this project, that stretches out for more than eight miles, is the means of intercommunication provided. It is a short-wave radio hook-up that enables men on the various contracts to talk not only among themselves but also with the different contractors' headquarters and the San Francisco office of the state engineer. There are now some 1,450 men at work on the bridge, while another thousand or so are producing steel and other necessary materials on the Pacific Coast and in the East. January 1, 1937, is the date set for the completion of the structure.

The entire undertaking is estimated to cost $75,000,000 and is being financed by the California Toll Bridge Authority of which Gov. James J. Rolph, Jr., is chairman and Earl Lee Kelly, Director of the State Department of Public Works, is secretary. The Reconstruction Finance Corporation is periodically purchasing portions of an allottment of $61,400,000 worth of 4½ per cent revenue-bearing bonds with the stipulation that the Toll Bridge Authority finance the ground approaches estimated to cost $6,000,000.

The work is under the supervision of Earl Lee Kelly, with Charles H. Purcell, chief engineer; Charles E. Andrews, bridge engineer; Glenn B. Woodruff, engineer of design; and W. G. Swanson, administrative assistant to the chief engineer. Consulting engineers retained include: Ralph Modjeski, Daniel E. Moran, Leon S. Moiseiff, Charles Derleth Jr., and H. J. Brunnier.

The Art Side of Sand-Blasting

EARL AVERY

A LOS ANGELES store recently imported four entrance door panels, made of 1-inch plate glass deeply carved with an intricate sand-blasted design, with which to decorate the front of the establishment. They were made in France by Lalique. American sand blasters, those that have not succumbed to the lure of quantity production, can and have produced examples just as fine as those doors. Artwork, in itself, requires time and patience, whether it be a fine painting or an ornamental panel of wood, glass, or metal produced by sand-blasting, and it is therefore understandable that it can have nothing to do with quantity output and speed.

The craft of sand-blasting various materials so that they can be used for decorative or practical purposes lends itself, however, to both classes of work. Glass, for example, can be embellished in this fashion quickly and at low cost, or it can be handled painstakingly at greater cost to obtain a more beautiful or more elaborate effect. It all depends on the buyer's pocketbook. Just what can be done in this direction is strikingly brought out by some of our photographs which illustrate, on the one hand, simply designed sand-blasted glass screens, valences, etc., that can be turned out in quantity, and, on the other hand, a bas-relief of exceptionally artistic merit. The frieze was made under the direction of di Lauro, and by a process developed by him. It consists of three panels having a total length of approximately 33 feet, a width of 7.5 feet, and a thickness of 1.5 inches, and shows a group of wild animals on the run. In this case, the depth of cutting alone—no color, no other medium, is depended upon to bring out the details of the "picture" and to give the effect of light and shade. Obviously, all this calls for skill and careful execution.

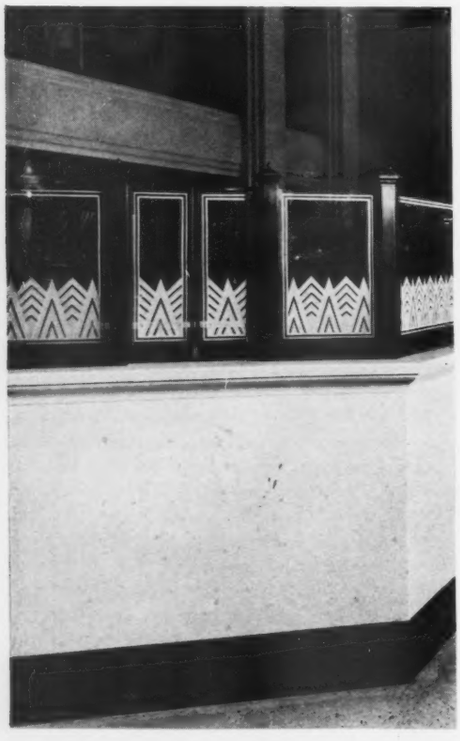
The field of usefulness of this branch of the sand-blaster's work is well-nigh unlimited. Materials such as wood, glass, marble, tile, pottery, etc., ornamented by him have a wide application in architecture; they are employed in the manufacture of advertising and display signs of all descriptions; department stores and gift shops display objects of art and novelties which he has decorated; and makers of lighting fixtures stay up late nights creating intricate designs for him to worry about. A partial list of other commodities that go through his hands might be worth mentioning here, as it emphasizes the extent to which sand-blasting is now utilized. This list includes: door and wall panels; transoms and skylights; show-window valences and backgrounds; counter screens and partitions for banks and other establishments; show cases; mirrors; clock dials; desk, table, and dresser tops; tableware; boxes of all kinds; furniture; pictures and portraits; etc., etc.

For repetitive work—quantity production, the pressure type of sand-blasting machine provided with a mixing chamber that enables the operator to regulate the flow of sand and air is the most suitable. In units of this type, compressed air is forced into the top of a tank and exerts pressure against the free surface of the contained sand, which is forced through a flexible hose to the nozzle by way of the mixing chamber. With the exception of the nozzle, the equipment is much the same as that used for cleaning. Air pressures vary from 80 pounds on up to 150 and more. High air pressures are not required except from the standpoint of production: the lower the pressure, the finer the work, and the longer it takes to do it.

THEATER LOBBY DOORS OF WOOD, STAINED, THEN SAND-BLASTED

BAS-RELIEF DESIGN BY DI LAURO ON A 33-FOOT GLASS PANEL

A compressor plant that is proving exceptionally efficient for sand-blasting generally is one consisting of a 2-cylinder, vertical, motor-driven machine delivering air at a maximum pressure of 125 pounds at the rate of about 118 cfm; of an automatic unloader; of an aftercooler between the compressor and the receiver; and of a moisture separator between the receiver and the sand blast. The unloader, which can be set to shut off the compressor and to start it up again as may be desired within its pressure range, considerably helps to cut down the power bills, while the aftercooler and the separator serve to free the air of moisture. If this be not done, the sand at the delivery end of the nozzle is sure to be damp and to cause the operator much trouble.



BANK SCREEN

Two-process sand-blasted glass surmounting the counter of a cashier's cage.

For art sand-blasting, it is the general practice to use nozzles with ¼-, ⅛-, and 1/16-inch openings. Fine work is done with the ¼-inch size; still finer work with the ⅛-inch; and the 1/16-inch nozzle needs a patient operator. In short, each has its own field of application; and the smaller the opening, the longer the time required to cover a given area. Today, hard-metal nozzles are being substituted for the old cast-iron, interchangeable type that wore out so fast that the business end of it had to be renewed several times on a busy day. The former, by retaining the diameter of its discharge opening, is said to give hundreds of hours of effective service.

Of late a new vogue, so-called carving, has started among sand blasters. There is no set method by which this work is done, but to do it well it needs low-pressure air and a 1/16-inch nozzle—sometimes one of ⅛-inch is adequate. It takes more time than ordinary sand-blasting, costs more, and, in the final analysis, has a more limited field of application. For artistic, shaded carving, the induction, suction, or gravity type of sand blast is most suitable because of the ease with which the operator can control the flow of sand and air. Unlike the pressure machine, the sand and the air are each run through a separate hose line terminating at the nozzle, which is much like the spray-paint gun in appearance and action. By means of a trigger at the gun—right at the finger tips—the operator can regulate the force of the sand blast to meet his requirements or that of the design that he is reproducing.

Beach and silica sands are commonly used in art sand-blasting. The finer the grade, the finer the finished product, and the longer it will take to turn it out. Abrasives of 60, 80, and 100 screen or mesh cut satisfactorily; but for high-class work a grade of the consistency of talc may be needed. This can be obtained by breaking down any one of the aforementioned sizes—running it at full pressure through a large sand-blast nozzle and against a piece of sheet iron. The residue from the exhaust tank of the dust-removal system, when thoroughly dried, also makes a good cutting medium for fine work. Silica sand, because of its edge-retaining quality, can be used over and over again, and is therefore reclaimed and regraded.

For the making of stencils that resist the abrasive action of the sand, glue manufacturers have placed on the market a number of special preparations known variously as "rubber", monument compound, dope, etc. They are preferred to home-made resistants, and can be purchased in cakes of 10 and 20 pounds ready for melting in a double boiler. They are usually applied with a brush at a temperature of approximately 90°F.; and, as a rule, the surfaces are given two coats to eliminate thin spots and bubbles—the first, a light one, being allowed to dry for a few hours before the second and heavier coat is laid on. These preparations can be employed again and again if proper precautions be taken to keep them free from sand and dirt.

Another form of resistant for the better class of work comes in sheets and rolls ready for application by simply moistening. It can be used within a few minutes, whereas the fluid compounds require drying and setting of from four to ten hours, depending upon the humidity. In the latter case, the practice is to coat the glass, metal, tile—in fact all materials but wood, in the late afternoon; to permit them to cure over night; and to cut the stencils the following day. Wood is given a heavy coat of shellac and powdered silica before the "rubber" is applied, as just described. The sheet material, besides being more expensive, cannot be re-used unless the shop is equipped to remove its paper backing and to flow the plastic

ANEL WHICH WAS SHOWN AT THE FRENCH COLONIAL EXPOSITION IN 1931

compound on to new sheets. Sand blasters, however, find it pays to keep some of it on hand to take care of rush jobs. For quantity production—that is, where the same design has to be repeated many times, stencils of fiber, rubber, metal, and sometimes of wood are utilized. Shops that do much work of this kind are equipped with motor-driven stencil-cutting machines.

The designs are drawn directly on the "rubber" after it is dry, or they are transferred. This is done by placing the original drawings on top of it; following their outlines with a sharply pointed instrument or a stencil wheel; and then rubbing or tapping the perforations with colored chalk. Stencil knives are used to cut away as much of the material as covers the surfaces to be sand blasted. This work requires skill, and can be acquired only through practice. The knife must be sharp and pointed and held perpendicularly so that there will be no undercutting of the resistant, especially on curves, as this would tend to leave thin edges here and there that would soon be worn away by the sand blast and give the reproduced design ragged outlines.

Depending upon the effect to be obtained, the underlying material receives either a surface sand blast—frosting, in the case of glass—or it is exposed two, three, or perhaps four times to the cutting action of the abrasive. This is known as processing. The various depths to which the design is to be carried are indicated on the original pattern, and these figures are transferred with the drawing to the "rubber" coating and serve the operator as a guide. Stencil-cutting, however, is not done in its entirety at the start, as in the case of frosting. Instead, the areas are exposed progressively—those to be cut deepest being uncovered and treated first.

Let us assume that a design is to be reproduced by 3-process sand-blasting. The first step involves cutting the deepest part or parts of the pattern to a point about one-third down; the second involves carrying the next cut of lesser depth down about half way; and the third involves making the finishing cut, at which time the entire motif is exposed to the abrasive action of the sand. After each process, the operator has to remove more of the plastic material; and with each attack of the sand blast the preceding cut or cuts are carried proportionately deeper until, at the end, all of them have attained their specified depth. In this work of processing, it is possible by means of different grades of sand—fine or coarse; different pressures; and different angles of approach to get varying effects that are pleasing to the eye.

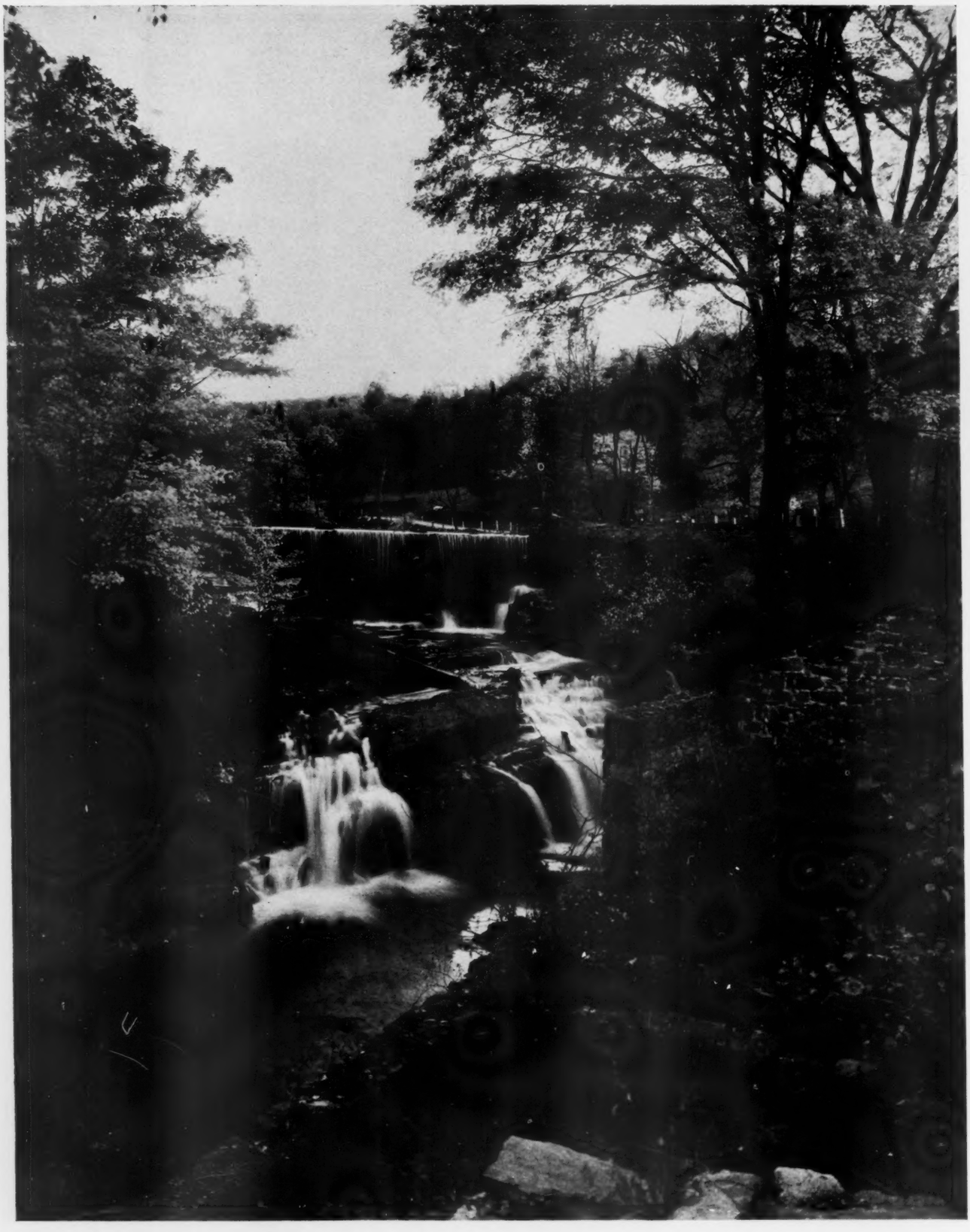
When the work is finished, the operator cleans the surfaces—and, incidentally, the resistant still adhering to them—with a blast of compressed air. As previously mentioned, the "rubber" is reclaimed for re-use. Its removal presents no difficulties when the atmosphere is moist: when dry, however, it is apt to harden and has to be dampened. This can be done by applying cloths that have been dipped in water and wrung fairly dry. When their contained moisture has been absorbed by the underlying compound, the latter can be peeled off easily.

Color, now so much in demand, is extensively employed to add a note of warmth to glass. It is applied to the rough surface by hand or by spray gun. Many transparent dyes are available for this purpose; and, even though they are not claimed to be sunfast, they retain a sufficient amount of color to warrant their use

Superficial sand-blasting requires little experience; an even movement back and forth across the surface regardless of the position of the designs assuring very satisfactory results. Skill, however, is needed to turn out a well-modeled, carved, piece of work. It takes time to learn how to hold the gun or nozzle and just what air pressures to use to achieve certain results. Shaded and "speckled" effects are obtained by varying the pressure and the distance of the nozzle from the object; others are produced by angling blasts—that is, by changing the position of the gun in relation to the surface attacked; while still others can be attained by holding the nozzle close to the work for an instant—concentrating on one spot, and then sand-blasting out from this deep center. With a gun with a small-diameter opening, and with air under perfect control, men that have become expert can "shoot" broad designs even without the aid of a stencil.

THEATER DOORS

Close view of designs worked on wood by first staining and then sand-blasting.

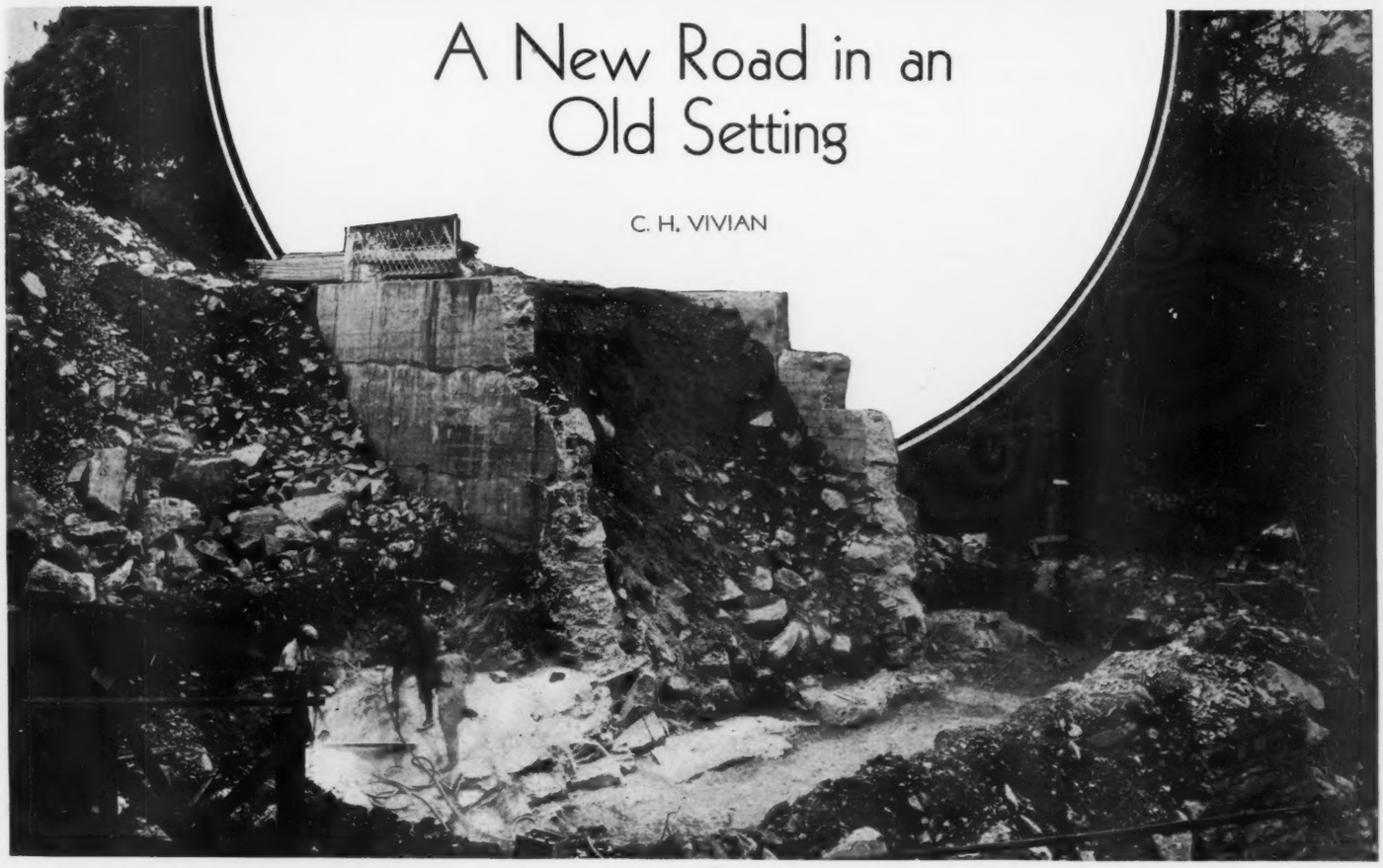


A SOURCE OF POWER FOR 150 YEARS

This waterfall at Bellvale, N. Y., furnished power for a clandestine iron forge built in 1745 to circumvent the tax imposed by the British on implements of their own manufacture which they exported to colonial America. Following this initial industrial venture, a long succession of mills of various sorts, a tannery, and another iron-working plant came and went along the banks of Longhouse Creek below the fall. Most of them were destroyed by fire. Ruins of the foundations on which some of these structures rested are visible at the lower right.

A New Road in an Old Setting

C. H. VIVIAN



THE OLD MAKES WAY FOR THE NEW

Three bridges have spanned Longhouse Creek at this particular point, and a fourth is now in the making. A wooden structure was erected there in 1808 when the Bellvale-Monroe Turnpike was laid out. In 1832 it was replaced with a masonry arch bridge. A concrete bridge was built on top of this in 1906. Now the contractors are tearing out the roots of the older structures to gain a footing for the new one.

ON July 1 of this year the Federal Government made available $400,000,000 for road construction and improvement in the various states. This sum represents about one-eighth of the $3,300,000,000 public-works fund created by the National Industrial Recovery Administration for the purpose of stimulating employment. All the road money is to be spent within two years from the time it was allotted; and those charged with its administration have acted with such dispatch that already upwards of 2,500 separate projects in all parts of the country have been started.

There is something more to the movement than the mere broadcasting of dollars. The total fund was allocated among the various states on a basis of their unemployment rolls, the idea being to take up slack proportionately throughout the nation. Within individual states, recommended projects must satisfy two requirements before the Bureau of Public Roads will approve them for construction. First, there must be a public need for the prospective improvement; second, it must be situated in an area where there is idle labor which can be thus put to work. If these conditions are met, the communities where the money is spent will receive temporary benefits in the form of payrolls and will, in addition, come into possession of permanent assets represented by better avenues of transportation and communication.

Within a few hours after the announcement from Washington that the money was available, the various state highway organizations were poring over plans and making decisions as to which of the projects in their jurisdictions should first be brought forward for approval. Fortunately, there was a backlog of necessary undertakings on which the essential preliminary engineering had been completed and which had been pigeonholed pending the securing of funds with which to carry them through. Coöperation between these state agencies and the Bureau of Public Roads resulted in the slashing of the usual red tape, and paved the way for speedily putting the first of the projects under construction.

In New York State, whose allotment of $22,000,000 was second only to the $24,000,000 awarded Texas, one of the first jobs to get underway involved the reconstruction of a road between Warwick and Greenwood Lake. This is a 5.47-mile section located in Orange County just over the line from northern New Jersey and in an area close enough to New York City to place it well within the range of 1-day automobile travel from that metropolis. Agreement as to the need for this improvement was reached with so little delay that all preliminaries were disposed of and the road actually put under construction on September 1, only 60 days after the Government's announcement.

Officially designated as Federal Aid Project 680-A, this piece of work is in the hands of the Lane Construction Company, of Meriden, Conn., a firm well known in the New England contracting field. It was awarded the contract on a bid of $282,425.50, and is obligated to complete the specified construction by September 1, 1934. The work includes clearing the right of way, bringing it to grade, and surfacing it with reinforced concrete.

The new road traverses an area that combines scenic charm with rich historical interest. From either end it winds upward to cross Mount Peter at an elevation of about 650 feet above the surrounding territory, which unfolds to the view of the traveler as a great green tapestry composed of rolling farmlands and wooded plots with here and there a glistening lake. At its eastern extremity is Greenwood Lake, an elongated body of water of rare beauty that lies 600 feet above sea level and attracts thousands of bathers and outers during the fair-weather months of the year. At the opposite end of the section is Warwick, an enterprising and neatly kept village that has a population of 2,500 and dates back to pre-Revolutionary War days.

About midway on the road under construction is Bellvale, concerning which it is recorded that 42 of its 300 souls took part in the War of Independence. In colonial times it was called

Wawayanda; and there is ample evidence that before the coming of the white man it was a populous Indian center. The neighboring countryside has yielded a profusion of arrowheads and other articles, including a large number of flint chips which were evidently used in the cultivation of corn and tobacco.

Bellvale owes its existence to the fact that at that point a small stream forms a waterfall which was a source of power for the operation of essential colonial industrial plants. The stream is called Longhouse Creek, a name derived from the elongated Indian dwelling house that formerly stood on its bank at the present site of lower Bellvale. It was the custom of the redmen in that region to build their homes end to end, and in following out this practice they eventually created one long structure.

During colonial days it was unlawful to work iron beyond the pig and bar stages. England reserved to herself the right to manufacture finished products, and derived a considerable revenue from their sale in America. The colonists naturally resented this edict, and conducted clandestine operations to evade the tax which the mother country imposed upon iron articles sent by her to this country. The crown was continually on the alert to discover and to suppress these forbidden manufactories. Not far from Bellvale were deposits of lean iron ore which were worked extensively until the discovery of the huge bodies of far richer ore in the Great Lakes region. The proximity of this raw material, and the relative seclusion of the Bellvale section, led Lawrence Scrauley to establish there in 1745 a forge or tilt hammer for a plating and slitting mill, which was operated by power from the waterfall previously mentioned. There was a demand for his product from blacksmiths and builders who readily purchased the convenient sizes of iron which he furnished them without the tribute they previously had been obliged to pay to the mother country. Scrauley's infant industry had a short life, however. In 1750 the crown became alarmed over the fall in revenues, and directed the British governing officials here to seek out and to close all colonial plants engaged in making implements of iron. It is related that the Bellvale forge was the only one the governor of the Province of New York discovered in his territory. It was put out of operation after only five years of service, never to resume.

The waterfall on Longhouse Creek continued to attract industries of various sorts, however; and until 25 years ago—almost without a break over a period of nearly 150 years—its power turned the wheels of mills and other manufacturing plants. In 1760 Daniel Burt built flouring and sawmills there; but they burned down after a few years of operation. Nathaniel Jones erected a wool-carding mill there in 1810. This was subsequently enlarged for the manufacture of broadcloth by Joseph Brooks. Later there was also a tannery near the fall. A sawmill ran for a time after 1812; but it was put out of commission when the dam which supplied its water power was washed out. A second iron-working plant was established by a Mr. Peck early in the nineteenth century. It produced agricultural implements for the farmers of the region; and during the War of 1812 turned out bridle bits, stirrups, and saddletrees for our cavalry.

Relics of all these manufacturing activities and of others which followed them survive in the form of numerous masonry foundations and other structures which are distributed along the streamside below the waterfall for a distance of several hundred yards. As recently as twelve years ago an attempt was made to utilize the water power in connection with an electrical process for the smelting of the nearby iron ores. This plan was advanced by a wealthy woman resident of Warwick who was an ardent student of metallurgy. A large-diameter, wooden-stave pipe was constructed to carry water from a dam just above the waterfall to a point several hundred yards downstream, where several large buildings were put up and equipped with machinery to be operated by hydro-electric power. The plant was run for only a short time, its closing having been ascribed to the high cost of extracting iron by the revolutionary process in use. When the Lane Construction Company took up its present work there, these buildings proved excellently adapted to its needs, and they are now serving as field offices, garages, and supply bases.

Below the waterfall, Longhouse Creek has carved a steep-walled gorge which has been crossed at one point by every road thus far constructed between Warwick and Greenwood Lake. When the contractors began their work, there was in use there a concrete-and-steel bridge dating from 1906, in which year the macadam highway now in service was built. This bridge was unsafe for heavy loads; and the project now underway calls for a new structure at the same site. When the contractors began to tear away the old bridge, they were surprised to find that it rested upon an earlier masonry arch bridge. Investigation disclosed that the lower structure had been

A SECTION OF ROADWAY UNDER RECONSTRUCTION

In some places the lines of the new and the old highways coincide, and the work consists of widening and improving the grade of the existing roadway. Approximately 35,000 cubic yards of rock must be drilled, blasted, and moved. Heavy drilling is being done with tripod-mounted drifter drills, one of which is shown above.

DRILLING SCENE AND BLACKSMITH SHOP

Dull drill steels are trucked to this semi-outdoor shop near the center of the work, where they are reconditioned with the aid of two sharpeners and an oil furnace that derive their air supply from the portable compressor shown. At the left are pictured drillers operating two of the fifteen "Jackhamers" that are in service.

built in 1832 and that it had, in its turn, replaced a still earlier wooden bridge which had become too weak to carry the loads imposed upon it. The bridge which the Lane Construction Company is getting ready to erect will, therefore, represent the fourth generation of crossings at that particular spot.

The highway now under construction reverts to the line of a dirt road which was built 125 years ago. That thoroughfare was known as the Bellvale-Monroe Turnpike, and was laid out in 1808 to give the farmers of the Warwick section a shorter route for transporting their products to the markets along the Ramapo River. It reduced their haul about one-half. In order to secure an alignment having a lower maximum grade, the 1906 highway deviated from the earlier line in several places by taking a more circuitous route in negotiating the elevated points. The present return to the older course again shortens the distance of travel but increases the grades at some points in the road—grades which would have been rather steep for the automobile of 27 years ago which will prove no great obstacle to modern passenger cars and trucks.

The Lane Construction Company is carrying on its work in conformance with the special provisions which apply to all Emergency Federal Aid projects. Since the chief purpose of the Government in sponsoring the construction program, of which this is a part, is to give men employment, it is required of contractors that they use manual methods wherever this can be done without delaying the work unduly or detracting from its quality. Section 204 of the National Industrial Recovery Act specifically provides that certain operations shall be conducted by hand labor. Among the items placed in this class are: clearing small timber, trimming slopes in cuts and fills, trimming ditches, excavating trenches for pipe up to 24 inches in diameter, backfilling excavated material, digging post holes for guard rails, and painting structures. Where necessary, horses can be used in any of these operations.

All laborers must be chosen from certified lists furnished by the National Reëmployment Service. In this case, employees are obtained through the Middletown and Newburgh offices of this governmental agency. Whenever a particular type of worker is wanted, the contractor notifies this Federal employment bureau which selects a qualified man from its rolls and gives him credentials which he presents when he reports for the job. All laborers are drawn from the general locality in which the work is being conducted, and preference is given to World War veterans. In the interest of further creating employment, employees other than those serving in supervisory capacities are limited to 30 hours of work per week. As the operations are being carried on ten hours a day and six days a week, this calls for two complete labor forces. Under the plan adopted, one crew works from Thursday morning until Saturday night and continues the next week from Monday morning until Wednesday night, at which time it gives way to another crew which follows a similar schedule. Under these conditions the job under discussion is furnishing work for 225 men.

Minimum wages are specified for all classes of workers. The rate varies from 40 cents an hour for common labor to 90 cents an hour for skilled mechanical workers such as operators of concrete pavers, power shovels and cranes, and iron workers. In some instances the Lane Construction Company is paying more than the law provides, in accordance with a policy formulated during its long and successful experience. The specified wage for rock-drill operators is 60 cents an hour.

The contract calls for the excavating of approximately 35,000 cubic yards of rock and 56,000 cubic yards of earth. In the transfer of materials to sections which must be built up, there will be involved 370,000 station yards of overhaul. It is estimated that 27,000 barrels of cement and 73,700 pounds of structural steel will be required for the concrete paving and associated structures.

The completed highway will be paved with two 10-foot strips of concrete each 8 inches thick at the outer edges and 7 inches at the center. Over one stretch of 1,200 feet, where the road makes a sweeping curve east of Bellvale, a third 10-foot strip of concrete will be added, making the over-all width 30 feet. This section will have a grade of 8 per cent and, except for one short link of 10 per cent, will be the highest in the route.

At the outset of operations the contractor cleared the right of way, constructed the necessary detours, and began excavating for required culverts. Meanwhile, rock drilling

CONCRETE FROM OLD STONE FENCES

In clearing their land of field stone, the first farmers in the region used it to build fences or hedgerows. In some cases these marked boundaries, but most of them have had no significance for a long time. The contractors determined that the rock in these structures was suitable for concrete and will so utilize it. In the view at the left the eye looks down a line from which has been removed a fence that formerly connected with the one shown. At the top right crews are at work gathering the stones. They are delivered to the growing mound (lower right).

was started at several points, men were set to work demolishing the existing bridge structures at Bellvale, and preliminary steps were taken towards setting up a centrally located plant for preparing concrete aggregates. Because of its complicated and composite structure, the old bridge gave more trouble than had been expected. Air-operated pavement breakers proved especially helpful in tearing it away, and several CC-45 machines were used.

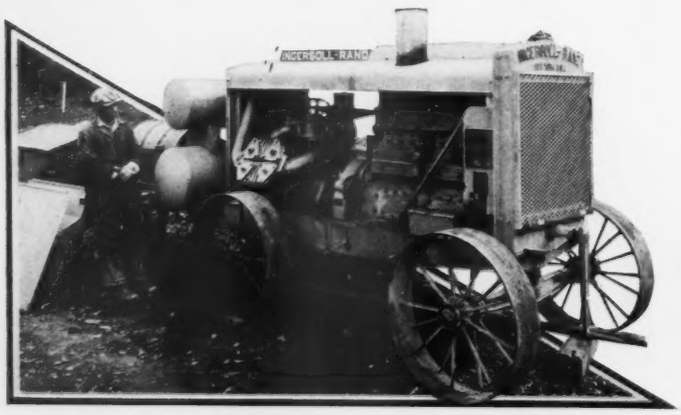
Both stationary and portable air compressors are being employed. Near the crossing of Mount Peter, on the eastern slope of that elevation, the rock work was heavy enough to warrant the setting up of one stationary machine. This is an Ingersoll-Rand Type XRB-2 unit which has a piston displacement of approximately 500-cfm. It is belt-driven from an Atlas 4-cylinder diesel engine.

Several portable compressors are in use, and one of these is of particular interest. This is a 370-cfm. unit of a type which has just been introduced by Ingersoll-Rand Company. The compressor is a 2-stage, air-cooled machine which has four low-pressure cylinders, arranged two on either side of a "V," and two vertically disposed high-pressure cylinders. It is driven by a 4-cylinder, 4-cycle engine which operates with fuel oil. Inasmuch as fuel oil contains up to one-quarter more power per gallon than gasoline, and costs anywhere from one-quarter to two-fifths less, the application of this new type of engine to portable compressors makes it possible to effect savings in fuel costs ranging as high as 65 per cent. The compressor on this contract has shown that it is capable of maintaining a pressure of 75 pounds while operating simultaneously three 60-pound "Jackhamers," or one "Jackhamer" of this size and one 220-pound drifter drill. In addition, there are three Ingersoll-Rand Type 20 portable compressors of conventional type in service.

Heavy drilling work is being done with X-71 drifter drills mounted on tripods. Three of these outfits are on hand. In some places, such as where the new road will follow the present one, there exist sloping faces of rock which must be removed to gain the necessary width. In those cases, a row of holes having a downward slope of a few degrees from the horizontal is drilled near the base of the rock face. By suitably spacing these holes, it is possible to break up all the overlying rock to sizes which can be handled by power shovels. The holes range up to 16 feet in depth. In other places the heavy tripod-mounted drills are used for putting down vertical holes. On some days these machines have averaged more than 100 feet of hole. Approximately fifteen "Jackhamers" of various sizes are also in service. Four of these are of the S-68 type, which has a 3-way throttle adjustment for regulating the speed of operation in accordance with the character of the rock being drilled. As much as 85 feet of hole per day per machine has been drilled. The rock on this contract is an altered sedimentary formation in which gneiss predominates and which, in places, approaches a quartzite. All of it is classed as hard drilling material which is highly wearing upon the gauge of the drill steel. Detachable bits have been used with some success, but most of the work is being carried on with solid drill steel.

Blasting is done with 40 per cent dynamite. Blasted materials are loaded into trucks by power shovels and hauled to fill sections where they are spread with bulldozers mounted on caterpillar tractors. Three power shovels are now in use on this work, and a fourth will be added. There are 24 trucks engaged in the hauling. Drill steels are reconditioned in a blacksmith shop which contains a No. 50 and a No. 34 drill-steel sharpener and a No. 26 oil furnace.

An interesting feature of this work is that the coarse aggregate for the concrete will all be secured by crushing field stone taken from hedgerows on farms in the neighborhood. A fleet of small trucks is now busy transporting this stone and forming a huge pile of it adjacent to the site where the foundations for the crushing and screening plant are being poured. Some of these fences were built well over a century ago. The material has been tested and passed upon as suitable for use in the concrete; and the farmers of the region are the gainers by having the strips of land on which these barriers rest cleared for them in addition to receiving remuneration from the contractor. The crushing plant will be equipped with two Acme crushers driven by a 2-cylinder, 140-hp. diesel engine. Diesel power will also operate the screens. The pavement will be laid with a Ransome 27-E paver. A temporary proportioning plant for the concrete required for culverts has been set up, and the mixture is being transported to pouring sites in truck-mounted transit mixers of 1½ cubic yards capacity.

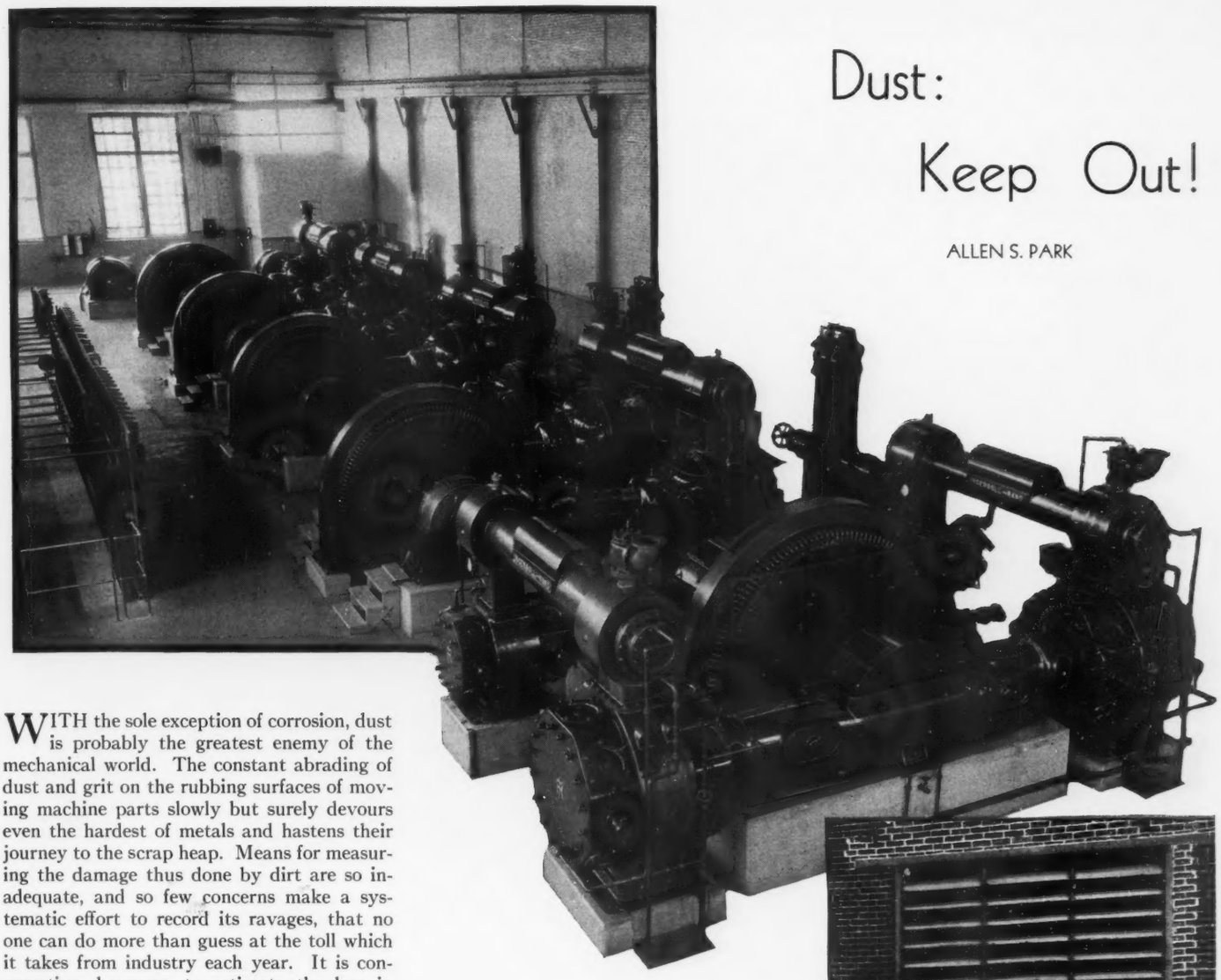


OIL-ENGINE-DRIVEN PORTABLE COMPRESSOR

This newly introduced Ingersoll-Rand unit combines the latest developments in both the driving and compressing ends. The compressor is a 2-stage, air-cooled machine. The engine is a 4-cylinder, 4-cycle unit which operates with fuel oil. This compressor shows surprising economies as compared with conventional water-cooled, gasoline-engine-driven machines. The unit pictured has a piston displacement of 370-cfm.

Dust: Keep Out!

ALLEN S. PARK



WITH the sole exception of corrosion, dust is probably the greatest enemy of the mechanical world. The constant abrading of dust and grit on the rubbing surfaces of moving machine parts slowly but surely devours even the hardest of metals and hastens their journey to the scrap heap. Means for measuring the damage thus done by dirt are so inadequate, and so few concerns make a systematic effort to record its ravages, that no one can do more than guess at the toll which it takes from industry each year. It is conservative, however, to estimate the loss in millions of dollars.

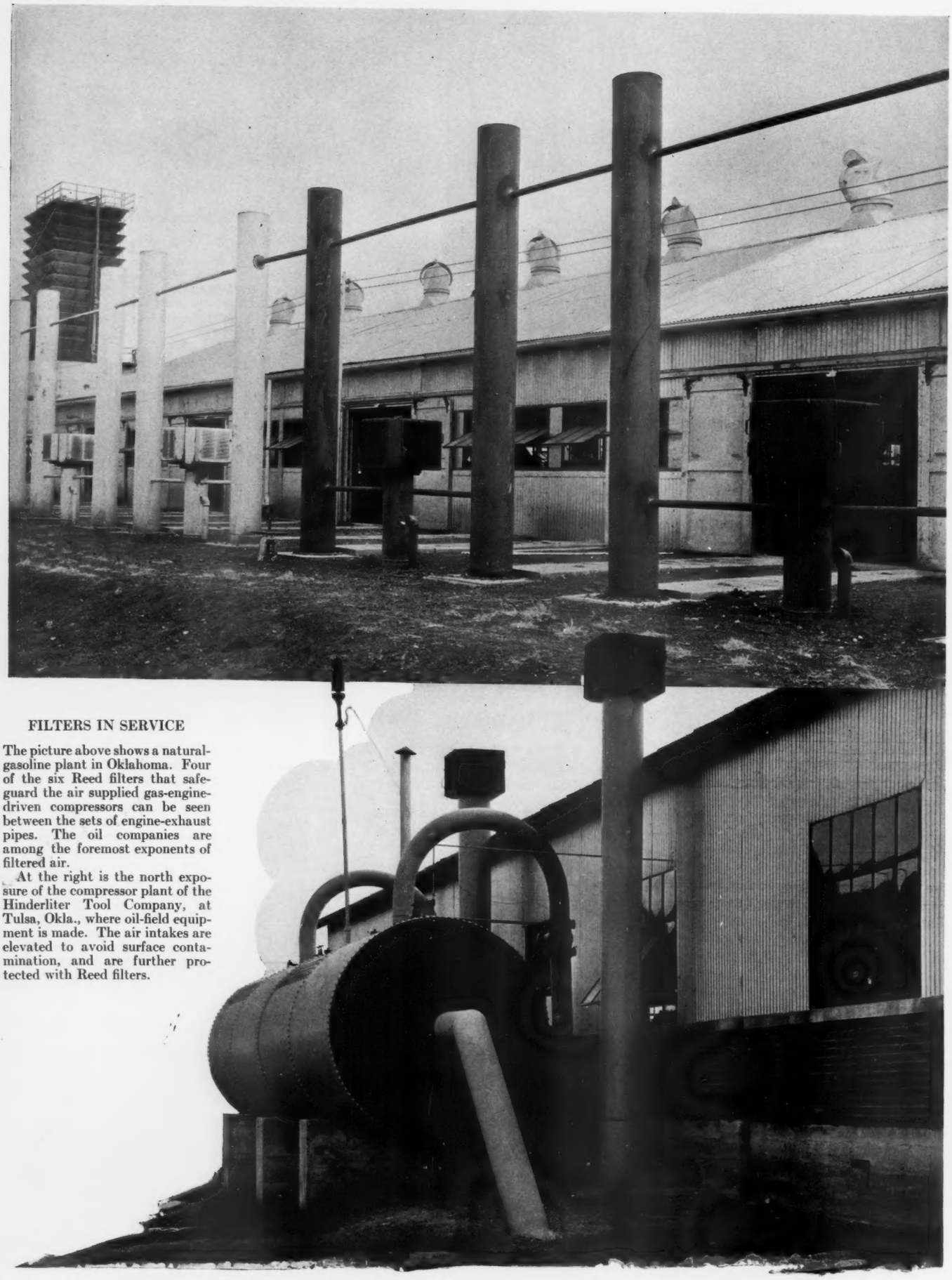
If you should visit some of the pumping stations distributed along the pipe lines through which crude oil is transported hundreds of miles underground, you would perhaps notice that many of those plants, although frequently in remote places, are surrounded by a sizable patch of well-kept grass. Your first impression might be that pride in the appearance of their properties impels the officials of those companies to plant and maintain lawns. Undoubtedly, this is one of the underlying motives; but, if you took the trouble to inquire, you would learn that those in charge are not so much concerned with attractive settings as they are with keeping dust outside of the walls that house the machinery. The grassy area which is so pleasing to the eye is, in reality, a resplendently attired guard that stands on duty 24 hours a day to thwart the efforts of machinery's arch enemy, dust, to break into a place where it isn't welcome. In addition to enlisting the aid of Nature, the companies usually provide mechanical facilities for cleansing the air used in the internal-combustion engines that drive the pumps.

It is not surprising to find one of the branches of the oil industry so wide awake to the penalties that grit exacts from machinery. Concerns in the business of supplying lubricants are keenly aware that dirt is a symbolical monkey wrench which commits sabotage on a wholesale scale if it is given half a chance. They know full well that dust not only cuts short the service life of countless pieces of machinery but, moreover, gives them inordinate appetites for lubricating oil and runs up bills accordingly.

Several classes of machinery are particularly susceptible to damage from dust for the reason that air is an essential agency in their operation. Air compressors can be placed at the head of the list, inasmuch as they fairly breathe the atmosphere at the rate of many inhalations a minute. Internal combustion engines probably are next most liable to damage from dirt, as air is also an important agency in their operation. There are other classes of machinery, such as motors and generators, which depend upon currents of air for the cooling of running parts. Air inevitably bears gritty substances in a finely divided state. Even the taking of air from within doors is no safeguard as to its cleanliness, for it is instantly replaced by an equal volume

INDUSTRIAL COMPRESSOR PLANT

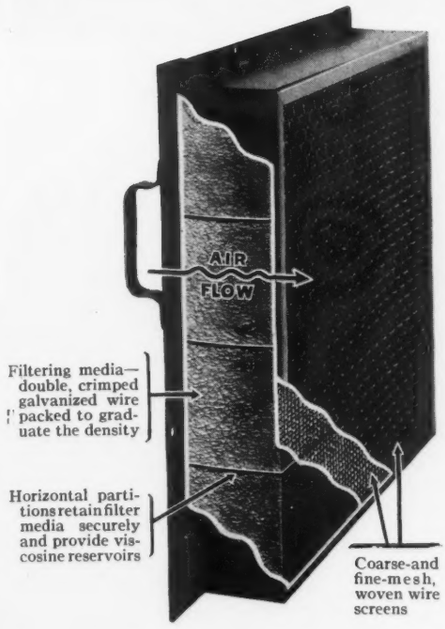
These five compressors have a combined capacity of 25,000 cfm. and furnish 100-pound air for many purposes in the Phillipsburg, N. J., factory of Ingersoll-Rand Company. The machine in the foreground has compression cylinders at all four corners, with an intercooler serving the pair at either end. It is driven by a 1,250-hp. synchronous motor. The air supply for these units enters the north wall of the building through the louvered opening seen in the lower picture. It passes through an American Type S continuous service filter housed in the compartment shown at the far corner of the compressor room. A cross section of such a filter appears on the next page.



FILTERS IN SERVICE

The picture above shows a natural-gasoline plant in Oklahoma. Four of the six Reed filters that safeguard the air supplied gas-engine-driven compressors can be seen between the sets of engine-exhaust pipes. The oil companies are among the foremost exponents of filtered air.

At the right is the north exposure of the compressor plant of the Hinderliter Tool Company, at Tulsa, Okla., where oil-field equipment is made. The air intakes are elevated to avoid surface contamination, and are further protected with Reed filters.


AIR FLOW
Filtering media—double, crimped galvanized wire packed to graduate the density
Horizontal partitions retain filter media securely and provide viscosine reservoirs
Coarse-and fine-mesh, woven wire screens

HOW A FILTER CELL WORKS

Cutaway section through a cell of an American filter. Each cell is 20 inches square and 4 inches thick. Cells are easily removable for cleansing. The capacity of the filter depends upon the number of cells comprising it.

from outside, and in spite of doors and windows dust comes in with it.

It is now recognized that there is no such thing as absolutely clean air. Even in the best-kept home a beam of sunlight, streaming in through the window, will reveal myriads of dust flecks. Scientists inform us that it is possible for the atmosphere to contain as many as 30,000,000 particles of dust to the cubic foot and still appear perfectly clear in ordinary light. These particles are, of course, almost infinitesimal in dimensions; but, nevertheless, a sufficient number of them can, when combined, produce an abrasive effect. Surveys show that the air in the average industrial center carries in suspension from 1 to 4 grains of dust by weight per 1,000 cubic feet. Considering the fact that a grain is only one seven-thousandth of a pound, this would not seem to be an amount worth worrying about. However, in the case of an air compressor, which literally feeds upon air, it is of vital importance. A fair-size stationary industrial compressor takes in 1,000 cubic feet of air every minute. If it operates 12 hours a day 300 days a year it will take in with the air somewhere between 31 and 124 pounds of dust in a 12-month period, depending upon whether the dust concentration is at the lower or higher figure given. The average dust ration of a compressor under such conditions is, therefore, 77½ pounds a year. Many compressors have capacities several times that of the one we have used as an example; and some low-pressure blowing machines in the steel industry have piston displacements as great as 22,000 cfm. In the face of these facts, there can be little doubt that enormous quantities of dirt regularly enter the working spaces of air-compressing machinery.

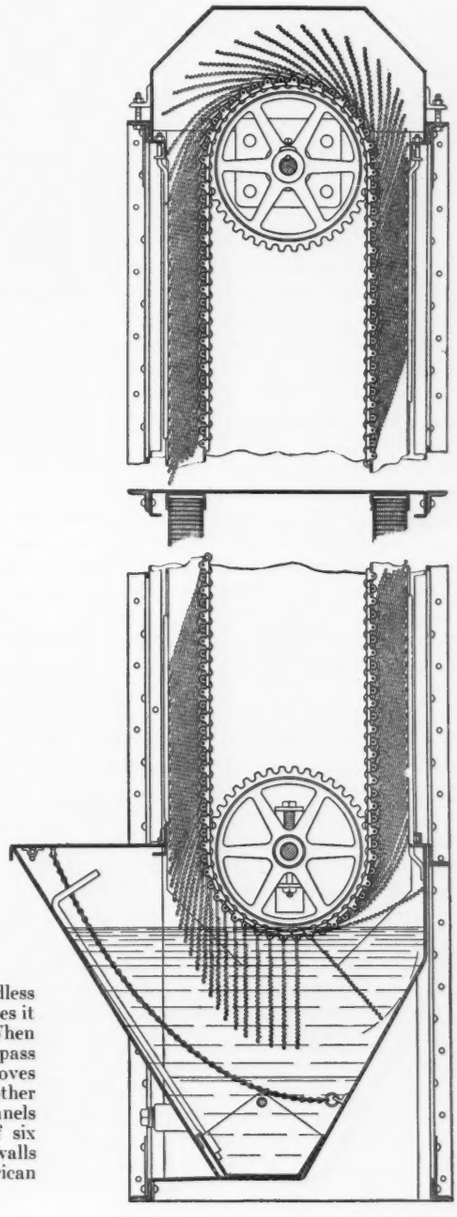
While a considerable proportion of this dust is not of a gritty nature, and much of it passes through the compressor cylinders into the discharge air lines, enough of it remains behind to constitute a real menace. Because of its adhesive nature, the lubricating oil traps measurable quantities of this dust and retains it in the cylinders. To understand more clearly just what takes place, we should consider briefly what happens to the lubricating oil. As is well known, such oil is not a single, homogeneous substance, but is a compound of a number of hydrocarbons which have different vaporization temperatures. Under the heat that is generated in the cylinder, small portions of the oil break down and vaporize. In reality, the process is one of fractional distillation on a miniature scale. The more volatile compounds vaporize first, and, as these pass off, the remaining mass becomes more viscous. As this process goes on continuously, there is gradually built up a thick, gummy residue of the less volatile constituents, and with this the dust mixes to form a gritty, paste-like mass. Although the individual particles of solid matter are for the most part exceedingly small, they constitute a multitude of minute cutting edges which in time score pistons and cylinder walls.

The oily films on both the intake and discharge valves likewise serve as catchers for some of the dust, and accumulations are gradually built up at those points. They not only share in the scoring of the valve seats, which hastens the time when new valves must be installed, but also help to constrict the air passages, thereby contributing to overheating and other undesirable conditions which gradually lessen the efficiency of the machine.

Considerable amounts of dust are carried into intercoolers and aftercoolers, and even on to the tools or machines that are driven by the compressed air supplied by them. In the intercoolers and aftercoolers the dust is deposited along with condensing oil vapors to form gummy accumulations similar to those in the cylinders and valves. These deposits reduce the efficiency of heat transfer, thereby raising the temperature of the air going into high-pressure cylinders or delivery lines, or both, and detracting from the general efficiency of the compressor plant. There is good reason to believe that, under the worst conditions at least, enough dust is carried on through the delivery lines to exert a detrimental effect within the tools and machines where the compressed air does its ultimate work.

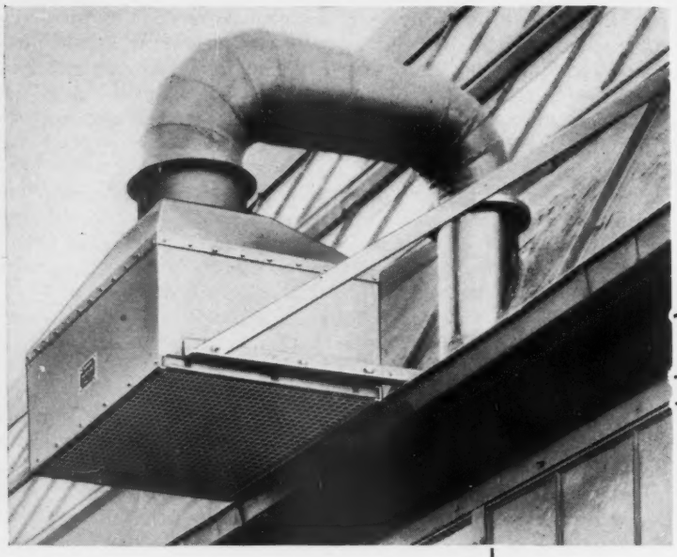
The black, gummy deposit—portions of which in particularly bad cases may eventually solidify into a solid mass on pistons and valves—is commonly believed to be essentially carbon. Careful investigation will show, however, that it consists largely of dust and grit. Many times the lubricating oil is blamed for offenses it does not commit. If a low-carbon-content oil is used, and is not fed to the cylinders and valves in excessive amounts, the carbon deposits traceable to the oil, alone, will grow at a very slow pace. It is probably not even fair to blame the lubricating oil for all those portions of the deposits which are definitely identifiable as carbon.

In industrial communities the air is laden with appreciable quantities of carbonaceous material in the form of soot, and it is entirely plausible that considerable of the carbon which accumulates in compressors does not have its origin in the oil but is in reality drawn into the compressing chambers with the intake air. For evidence in support of this theory it is necessary only to consult the records showing the contamination of the atmosphere in some of our representative cities.



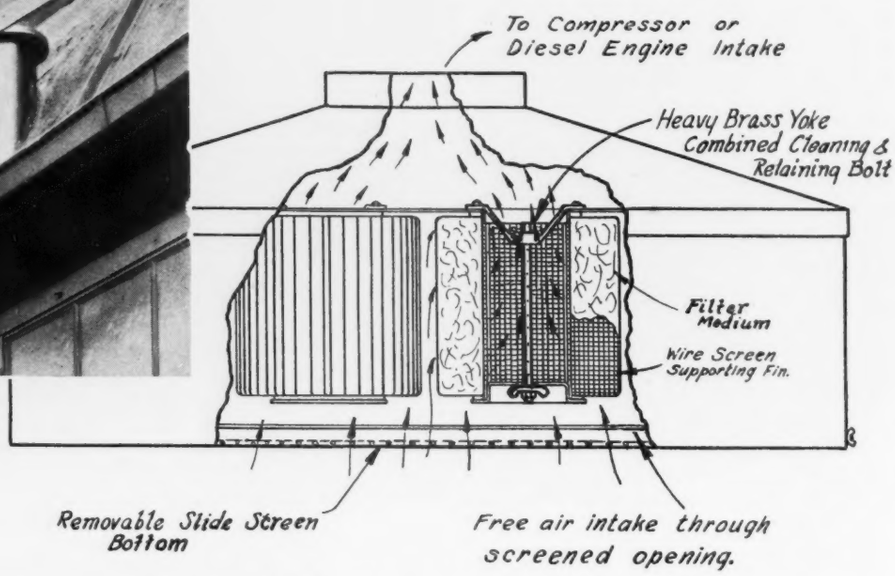
CONTINUOUS-TYPE FILTER

Corrugated-screen panels are suspended from an endless chain which rotates clockwise. Every twelve minutes it moves ¾ inch, or a total of 7½ feet in 24 hours. When they reach the bottom, the panels separate and pass through an adhesive filtering fluid which both removes the collected dust and recoats the screening for another revolution. When moving up and down the panels overlap to form two opposing walls made up of six thicknesses of screening. Through both of these walls the air must pass. The unit illustrated is an American Type S.



HANGING TYPE OF FILTER

This 1,500-cfm. Protectometer filter installed at a Detroit industrial plant is arranged to permit dust to fall from it by gravity. Filtration is effected by causing the air to pass through a dry filter medium which is fitted over wire supports. The accompanying sectional sketch illustrates the assembly of this unit.


To Compressor or Diesel Engine Intake
Heavy Brass Yoke Combined Cleaning & Retaining Bolt
Filter Medium
Wire Screen Supporting Fin.
Removable Slide Screen Bottom
Free air intake through screened opening.

During the month of September, just past, the air breathed by the people of Manhattan Borough, New York City, contained an average of 1.75 tons of soot and dust per cubic mile. On one day during that month it held an average of 3.25 tons per cubic mile, and for a 6-hour period between four and ten o'clock in the morning the figure rose as high as 5.58 tons. The Smoke Abatement League in St. Louis, Mo., found that during one November the fall of soot from the air averaged 775 tons to the square mile. Records were taken at nineteen different points in the city and its suburbs, and disclosed a range of soot fall from 77 to 2,880 tons per square mile, the lower figure having been obtained in a strictly residential section. During the month of December, when more heating plants were in operation, the average for the city as a whole rose to 909 tons per square mile. Figures comparable to those just cited can be obtained in almost any of our larger industrial communities. In the face of them, it would hardly seem to be open to doubt that large quantities of carbon are carried into compressors by the intake air.

Fortunately, it is possible to keep virtually all atmospheric dirt out of compressors and thereby forestall damage from this source. This can be done by installing suitable filters on the intake line. Highly effective devices of this sort are now on the market; and it is claimed for them that they save their cost within a surprisingly short time. All the leading compressor manufacturers recommend the use of air filters, as experience has proved them important contributors to the satisfactory and economical operation of their machines.

We do not have to look beyond the realm of everyday life to obtain a lesson in the value of clean air for machinery. The automobile that we drive is equipped with an air-cleaning device to eliminate dust and other foreign materials from the air which goes into the carburetor for mixing with the gasoline. This has not always been the case, as it is only within the past ten years or so that automobile builders have come to recognize the value of clean air. Barney Oldfield, the veteran racing driver, is credited with being one of the pioneer advocates of air filters. In published articles he revealed that the so-called carbon deposits in automobile engines consisted of only about 3 per cent carbon while the remaining 97 per cent was a mixture of various soluble compounds and dirt which had been drawn in through the carburetor air intake. His crusading is said to have been largely responsible for the inclusion of an air filter in the equipment of the modern automobile—an addition which has materially reduced the intervals at which the motorist must put his car in the shop for the familiar and unwelcome job known as carbon removal and valve grinding.

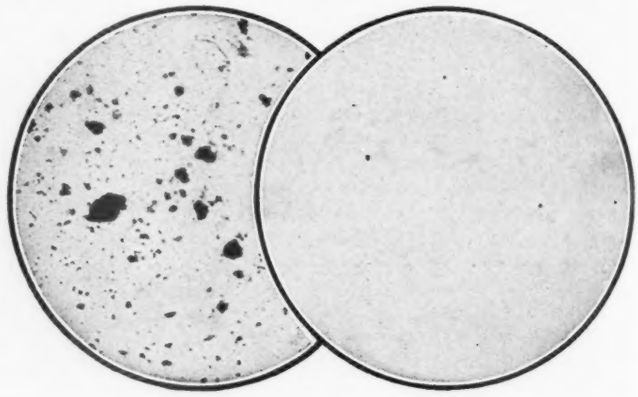
Bearing in mind that makers of automobiles have found it advisable to equip their engines with air filters, the comparatively greater need for such devices on air compressors can be readily shown. In the first place, the service life of a compressor is far greater than that of an automobile engine. Second, it uses air exclusively, and is therefore subject to greater damage from unclean air. Finally, it is, on an average, a more expensive piece of machinery and one on which the proper functioning of an entire plant frequently depends. Consequently, there exists a correspondingly greater reason for properly caring for it.

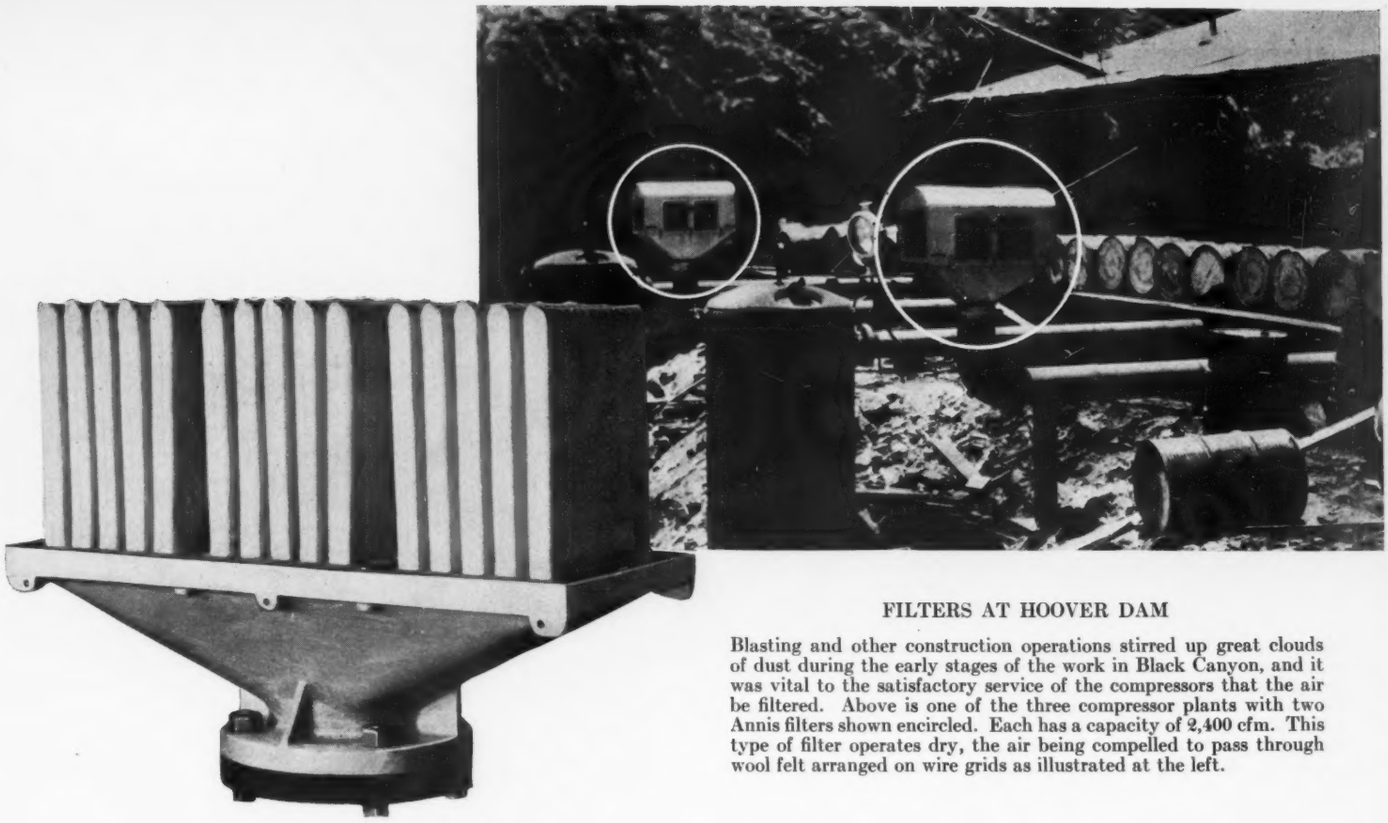
If an automobile is driven at an average rate of 30 miles an hour, it will have run 60,000 miles in 2,000 hours. Most car owners consider their machines practically worn out or, at least, ready to be traded in when they have amassed the mileage cited. On the other hand, a compressor that operates ten hours a day will have run 2,000 hours in but 200 days. A first-class machine is considered to be well broken in only after such a period, and the owner can look forward to many additional years of useful service from it.

Air filters suitable for compressors come in a wide range of types and sizes, which makes it possible to select one for any particular installation. In general there are two types: one for small plants, and one for large ones. The filters for small plants have removable air-cleansing elements which can be easily withdrawn for periodic cleaning and reconditioning. The filters that serve large compressor installations are designed for continuous ser-

RESULTS OF FILTERING

Microphotographs of dust samples. The particles in the left-hand circle were contained in ordinary atmospheric air which appeared perfectly clear to the eye. Similar air is shown at the right after having passed through a commercial-type filter.





FILTERS AT HOOVER DAM

Blasting and other construction operations stirred up great clouds of dust during the early stages of the work in Black Canyon, and it was vital to the satisfactory service of the compressors that the air be filtered. Above is one of the three compressor plants with two Annis filters shown encircled. Each has a capacity of 2,400 cfm. This type of filter operates dry, the air being compelled to pass through wool felt arranged on wire grids as illustrated at the left.

vice. They are self-cleaning and require no attention other than an occasional oiling of the mechanism which provides for their automatic operation. Several types of filters of various sizes are illustrated, and the principal features of their construction are described in the legends that accompany the pictures.

Independent surveys by unbiased observers clearly reveal that compressor plants operate more efficiently and at lower expense when they are equipped with intake air filters. Such a survey was made in Indianapolis, Ind., in 1930, at a compressor plant of one of the leading railroads. In this case, two compressors, having respective piston displacements of 610 and 710 cfm., were installed in the railroad yards where the air was unusually dirty because of the continual passing of locomotives and the handling of coal nearby. Considerable trouble was experienced with the operation of the machines prior to the installation of filters. Valves had to be taken out and cleaned once every 30 days; and they were usually found to be well coated with carbon and dirt deposits. When cleaning the valves, the machines were given a thorough inspection, which required ten hours' time by two men. The sixteen valves in each compressor were replaced every two years. Following the installation of air filters, the interval of valve cleaning was extended from 30 days to six months. Because of the fact that the valves were in better condition, only six hours' time by two men was needed for inspection as against ten hours. When the survey was made the filters had been in service three years, and during the intervening period it had been found necessary to replace only half the valves in the compressors. On this basis, the life of a complete set of valves was taken to be six years, or three times what it was before the filters came into use.

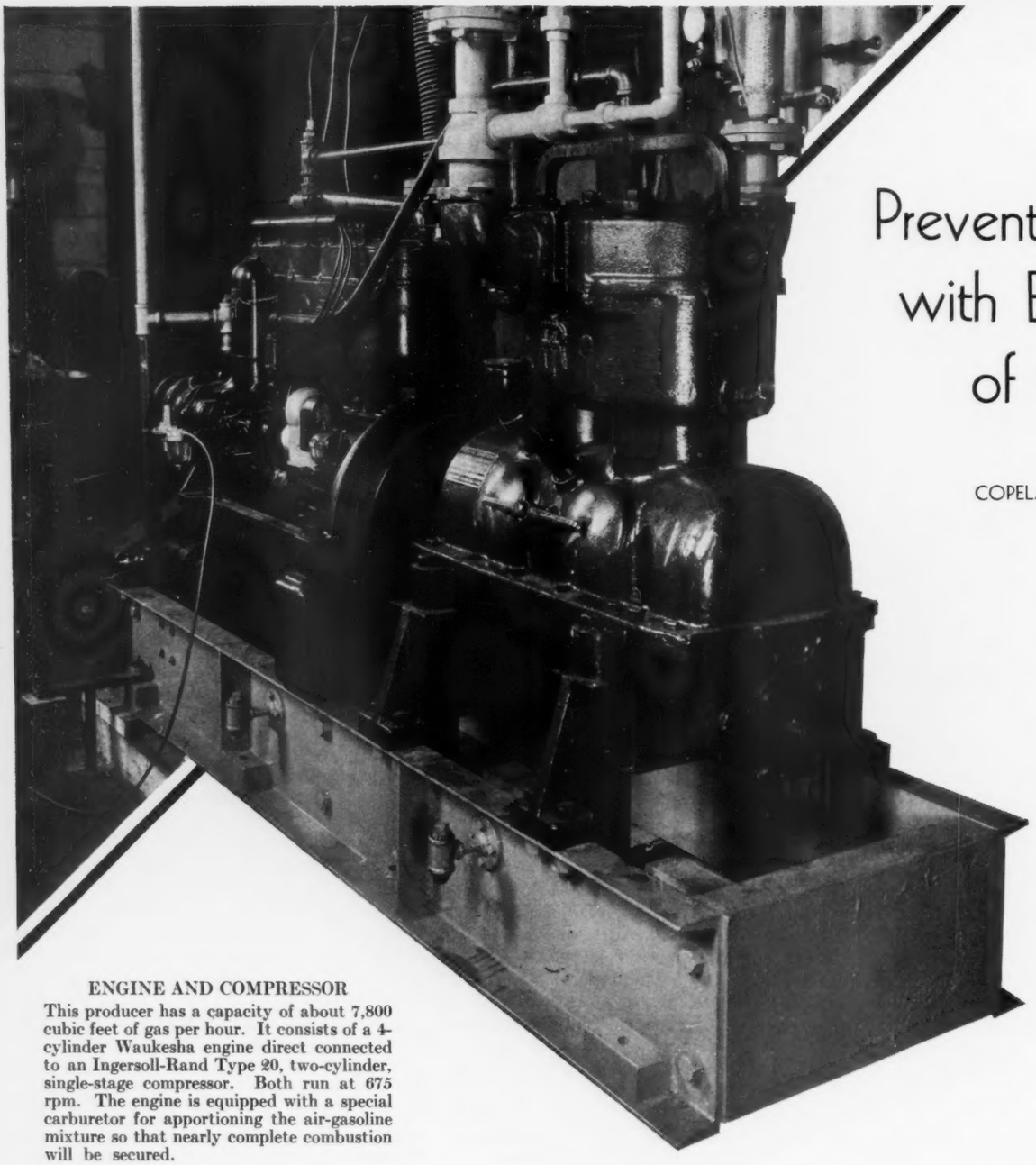
Before the filters were installed, the compressors were lubricated by a 3-drop sight-feed oiler. After clean air had been provided, however, a 2-drop oiling adjustment proved to be adequate, thus effecting a 33 per cent saving in lubricating cost. The total annual compressor maintenance expense was $411.77 before the installation of filters, and only $163.33 with them in operation. The difference, $248.44, amounts to a reduction of 60.3 per cent. As the annual cost of operating and maintaining the filters, including depreciation and interest, was computed to be $52.58, a net saving of $195.86 is indicated. As the filter installation cost $312, the original investment is returned at the rate of 62.8 per cent annually, or once every nineteen months.

An investigation of the comparative performance of compressors in a large automobile factory, when operating with and without air filters, gave generally similar results. In this case, the compressor plant consisted of eight machines ranging in piston displacements from 2,000 to 4,125 cfm. and having a combined piston displacement of 27,170 cfm. Prior to the installation of filters considerable difficulty was experienced in keeping the compressors operating satisfactorily. Over a 3-year period the total repair-and-maintenance cost was $10,005.60. Of this sum $6,645.60 was expended for labor in cleaning and repairing valves and cylinders; $1,560 went for material for valve repairs; $900 was spent in reboring six high-pressure cylinders; and $900 represented the cost of new pistons, rods, and rings.

During the three years following the installation of filters, the total repair-and-maintenance bill dropped to $2,059.20. It was found unnecessary to rebore any of the cylinders or to replace any of the valves, and the labor cost was greatly lowered. The indicated saving attributable to the filters was $7,946.40 for the 3-year period, or $2,648.80 annually. In addition to the reduction in repair-and-maintenance charges, the oil consumption was cut from 65 to 35 gallons a month. At 60 cents a gallon, this amounted to a further saving of $216 a year, making the total annual reduction in costs $2,864.80. After the subtraction of fixed and operating charges on the filters the annual net saving was $2,228.11. The annual return on the initial investment of $2,750 amounted to 69.9 per cent. On this basis, the savings resulting from the use of the filters were sufficient to pay the cost of the filters in seventeen months.

Although air filters have not been in general use long enough to compute their effect upon the service life of compressors, there is every reason to believe that they considerably prolong the service life of such machines. They can, therefore, safely be accredited with further economies, the determination of which must be left to the future.

All the advantages of filtering air for compressors apply in almost equal measure to internal-combustion engines. The explosive mixture in the cylinders of a diesel engine is only about 10 per cent fuel, the remainder being air. The chances of damage from dust are, accordingly, almost as great as in the case of air compressors. A 100-hp. diesel may draw in as much as 400 pounds of dirt in a year unless means are provided for cleaning the air, hence all the leading engine manufacturers advise filtration.



Preventing Fires with Blankets of Gas

COPELAND LAKE

ENGINE AND COMPRESSOR

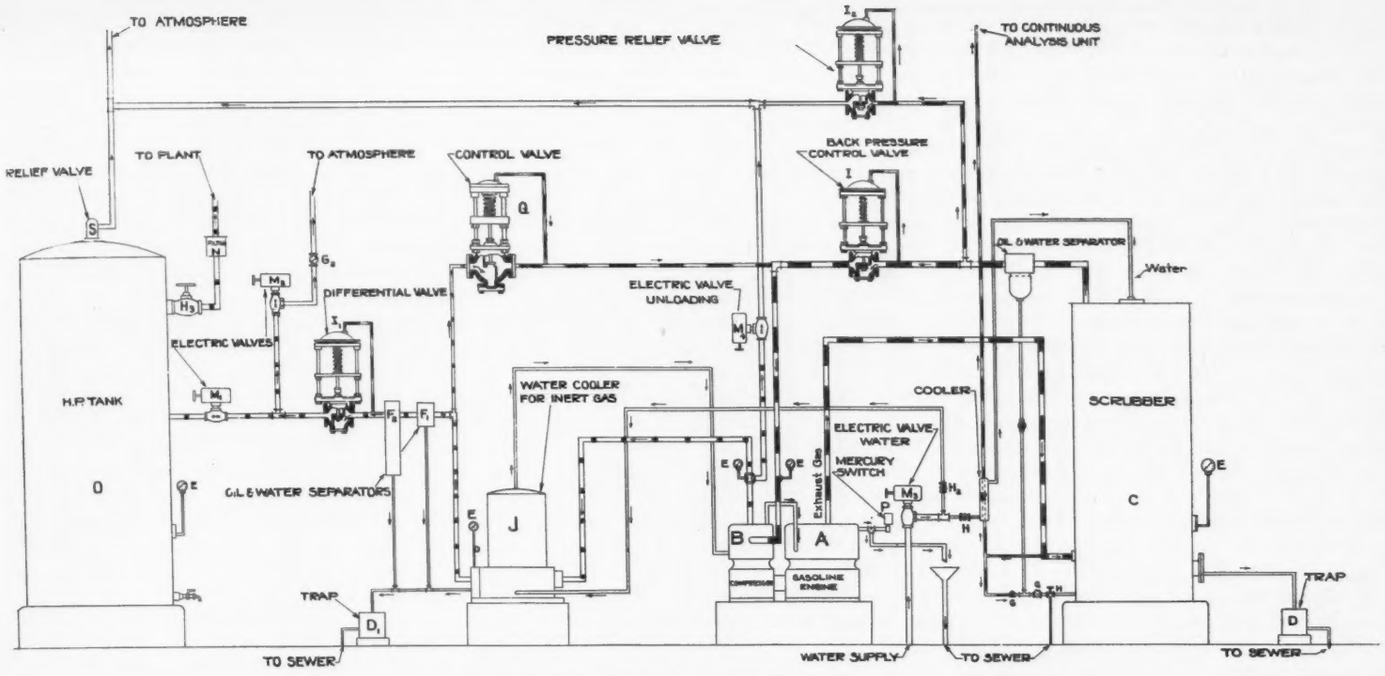
This producer has a capacity of about 7,800 cubic feet of gas per hour. It consists of a 4-cylinder Waukesha engine direct connected to an Ingersoll-Rand Type 20, two-cylinder, single-stage compressor. Both run at 675 rpm. The engine is equipped with a special carburetor for apportioning the air-gasoline mixture so that nearly complete combustion will be secured.

WE have made much progress in the matter of fire protection since that ill-fated moment on the night of October 8, 1871, when Mrs. O'Leary's cow is reputed to have kicked over a lantern and kindled the blaze that well-nigh effaced Chicago from the landscape. Although a great many fires still occur, they are relatively few considering the almost infinite number of hazards afforded by the complexities of our great cities and the magnitude of our industrial development.

We have reached our present comparative security because we have learned to be vigilant and because we have set up innumerable safeguards against fire. Such fires as do break out very seldom extend far from their points of origin, thanks to the efficient equipment and excellent training of our fire-fighting departments. Various fire-prevention methods and measures which were unknown at the time of the Chicago calamity are now commonplaces. Unburnable building materials, fire extinguishers, automatic sprinkler systems, and numerous other protective agencies have been either developed entirely or greatly improved during the intervening period. Millions of dollars are spent annually to reduce fire hazards, on the theory that an ounce of prevention is better than a pound of cure.

Despite our notable advance, however, there are many extraordinary fire hazards today that did not exist a half-century ago, and these demand special means of protection. The study of these, together with the determination of adequate safeguards to apply to them, has become a science in itself. Through the combined efforts of industries and fire-insurance companies, noteworthy headway is being made towards the elimination or control of these special dangers, and it is likely that the day will come when fires of mysterious origin will be rare.

Foremost among the fire sources of extraordinary character are explosions of various highly combustible substances which have come into widespread use in our ramified industry and commerce, and it is to these that the experts have devoted a large share of their attention. Their investigations have disclosed many startling but interesting facts. For example, we know now that the dusts not only of all grains but also of many other materials formerly regarded as harmless are in reality very explosive. Among them may be mentioned the dusts of alfalfa, malt, cocoa, potato starch, and aluminum. The U. S. Department of Agriculture has conducted extensive tests of the explosibility of products of the soil and determined measures for handling them with a minimum of hazard.



THE INERT-GAS-PRODUCER ASSEMBLY

Exhaust gas from the gasoline engine (A) is piped to the scrubber (C) where it is cooled and cleansed. Cooling water from the scrubber enters at the top and is discharged to a sewer through the trap (D) at the bottom. Oil and water are next removed from the gas by passing it through a separator, which is drained through the check valve (G) into the scrubber. When not in use, the scrubber is drained by means of the globe valve (H).

Control valve (I) keeps the low-pressure-gas system under a constant pressure of about ½ pound to the square inch, thereby exerting back pressure on the engine exhaust. Relief valve (I_2) opens to the atmosphere if the pressure becomes excessive. Control valve (Q) allows compressed gas to enter the suction line of the compressor to maintain pressure above atmospheric at the compressor intake.

The gas is compressed in the compressor (B) and flows through the aftercooler (J) and through the oil and water separators (F_1)and (F_2). The separated oil and water are discharged to the sewer through the trap (D). Differential valve (I_1) maintains a pressure of 105 pounds in the compressed-gas line back to the compressor, thereby providing a steady load for the engine. The valve (M_1) is operated directly from the analyzing board and allows gas to flow to the storage tank only when the carbon-dioxide percentage is satisfactory. If the carbon-dioxide content is below standard, the gas is discharged to the atmosphere by the automatic operation of the solenoid valve (M_2).

The high-pressure storage tank (O) discharges to the atmosphere through the relief valve (S) if the pressure becomes excessive. High-pressure gas flows through the globe valve (H_3), filter (N), and a reducing valve when being withdrawn for use.

A thermostat-operated mercury switch (P) closes the water valve (M_3) which supplies water for cooling all the equipment and opens the unloading valve (M_4) when the cooling water temperature is below a prescribed point in order to allow the engine to warm up before it is run under load.

The development of the internal-combustion engine and of highly specialized industrial chemistry has brought gasoline and other extremely volatile liquids into common use, and their handling during processing and transportation constitutes a distinct danger. It has been found, curiously enough, that these two classes of materials—dusts and flammable liquids—have markedly similar explosion characteristics. Determination of this parallel was important because it revealed that like methods could be applied for combating the fire hazard of both.

Elementary chemistry teaches us that oxygen is necessary to support combustion. It follows, then, that by sufficiently diminishing the oxygen supply we can prevent the combustion of any substance. Grain dusts will not explode if less than 12 per cent of oxygen is present, nor will starch. The safe oxygen limit for sulphur is 8.6 per cent; for hard rubber, 13 per cent; and for coal dust, 16 per cent. In view of these facts, it was only natural that fire-protection authorities seized upon the idea of preventing highly volatile substances from exploding or burning by reducing the oxygen content of the atmosphere surrounding them. Such a procedure is the basic principle of the protective system which we shall presently describe. Before doing this, however, it will, perhaps, be of interest to mention some of the specific hazards which require protection.

The lighter solvents and spirits which enter into the manufacture and processing of countless articles are among the sources of greatest danger. Where they are used in large quantities, there are usually at hand facilities for storage, and these constitute decided menaces because if fires or explosions do occur they are generally of such proportions as to endanger the lives of many persons and to damage a great deal of property. Extreme care must be exercised in filling storage tanks or drawing liquids from them, owing to the chance of ignition from such an unseen cause as static electricity. These tanks have to be cleaned periodically, and they are then particularly hazardous because they often retain mixtures of air and vapors in highly explosive proportions. Many unforeseen circumstances can produce sufficient heat to touch them off. Take, for example, the case of an underground carbon bi-sulphide tank at a rayon factory. This was being cleaned after it had been emptied and flushed out several times with a hose. Small quantities of the vapor remained, however, and after a time the odor became so pronounced that the workmen left to get their gas masks. When they were about 60 feet away the tank exploded. Fortunately, no one was seriously hurt. It was determined afterward that the carbon bi-sulphide in contact with the steel of the tank had formed iron sulphide. This acted in a catalytic way when a correct mixture of air and carbon bi-sulphide vapor passed over it and caused the vapor to become hot and to explode.

Gasoline is, of course, also dangerous, although less so than the more volatile liquids of the class just referred to. A stream of gasoline flowing from one container to another can easily become charged with static electricity. Similarly, gasoline swishing about in a tank truck or a tank car during transit can generate static. Even the pouring of the contents of one can into another will sometimes produce enough electricity to cause a fire. Because of the hazards of unloading or loading bulk gasoline and kindred distillates, ground connections are provided to dissipate any electricity formed. Perhaps you have wondered about the chain you saw dangling on the pavement from a passing gasoline truck. It is there by design—to transmit electricity to the ground, and is necessary because the rubber tires serve as insulators.

Empty tank cars, tank trucks, and drums used for gasoline transportation are especially dangerous for the same reasons as were given concerning the carbon bi-sulphide storage

tanks. It is a common safety practice to place empty gasoline drums vent upward and with the plugs removed, but even this precaution is sometimes not sufficient to avert disaster. In a recent case, a welder unthinkingly used such a drum as a work bench while repairing a wrench which a workman had brought him. The drum had lain in the yard for six months, but still contained an explosive mixture of vapor and air. The heat of the welding ignited this, and a bad accident was the result.

Countless explosions and fires have occurred in flour mills and cereal plants. In 1917, fires in southern cotton gins were so numerous that alien-enemy activity was suspected, but they were traced to static electricity. The aluminum-bronze industry in Germany has experienced a great many explosions. Spray painting of lacquers in confined spaces is recognized as extremely hazardous. A long list of materials and processes that present danger might be compiled, but the examples we have given suffice to emphasize the diversity of highly combustible substances and the extreme caution that must be used in handling them.

The causes of explosions and fires are numerous and varied and often hard to ascertain. In many plants a series of explosions had occurred before the source of ignition could be located. Static electricity is one of the most frequent causes, and its origin sometimes almost defies detection. Overheated bearings in machinery, heat from pulleys, and bursting electric-light globes are some of the more ordinary causes of fires in industrial plants.

It will be apparent to the reader that because of the variety of ways in which highly flammable materials can be fired and because of the difficulties of preventing the inception of the required heat, the most adequate safeguard available is that of creating an atmosphere in which no combustion can take place. As was previously stated, this can be accomplished by reducing the oxygen content in the atmosphere to a safe limit for the particular substance being handled. This can be done by replacing all or a part of the normal air in contact with the material with an atmosphere of inert composition. This procedure offers the greatest possible safety because, by maintaining pressure within the inclosed space, a leak will cause an outrush of the inert gas and will prevent air from getting within. Such a leak can be instantly discovered through the actuating of pressure-reduction alarms, when operations can be stopped until the necessary repairs are effected. Fire protection by the inert-gas method has been widely practiced, first in Europe and afterward elsewhere.

Singularly enough, all the known inert gases are constituents of the atmosphere of the earth, although some of them are present in only very small amounts. The most plentiful gas is nitrogen, which makes up a little more than 78 per cent of the air. Argon occurs to the extent of about 1 per cent, and helium, neon, krypton, and xenon are there in lesser quantities. In addition to these gaseous elements the air contains about .034 per cent of carbon dioxide, a compound formed through the complete combustion of carbon.

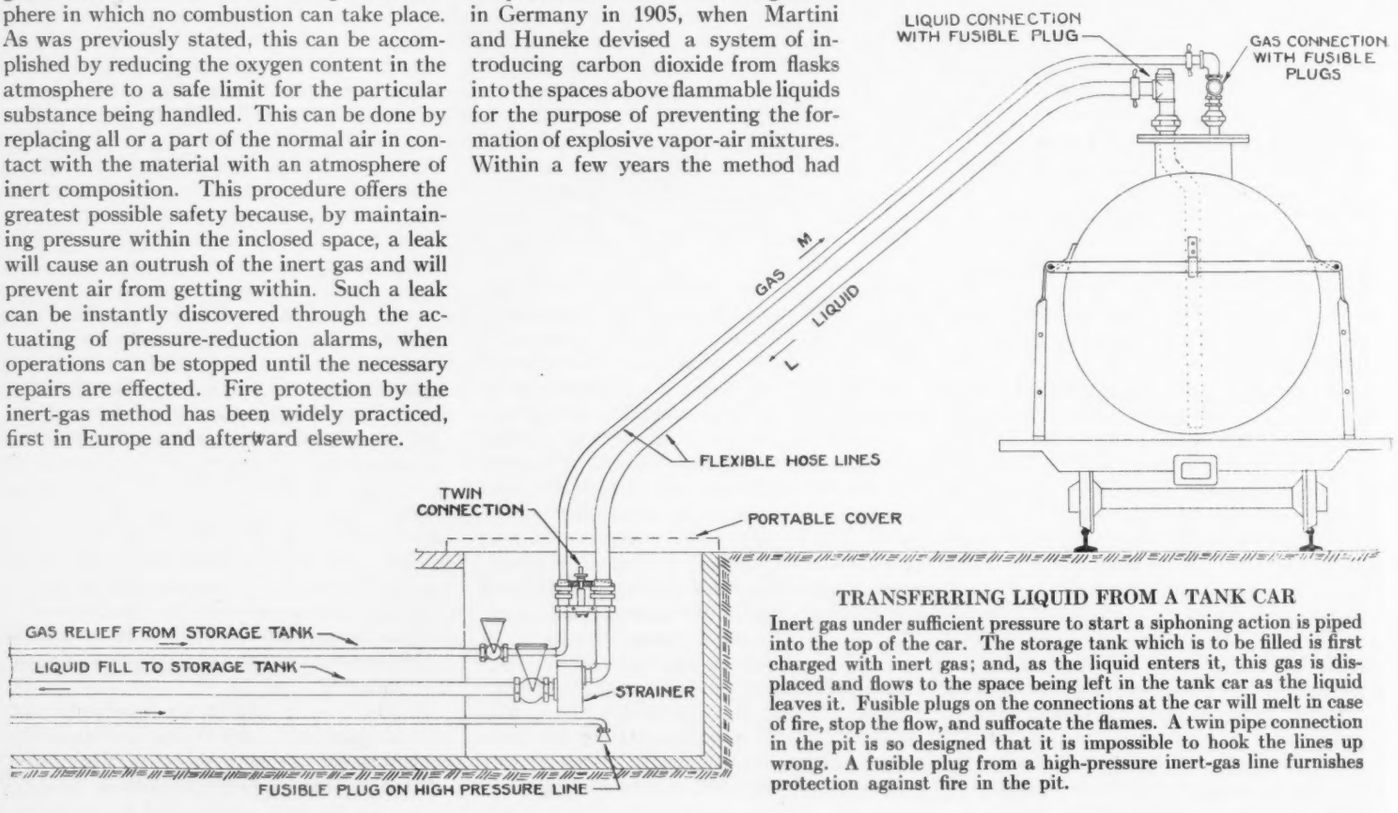
Helium is well known for its use in lighter-than-air craft. Employment of it for the purpose here under discussion is precluded by its cost. Nitrogen, because of its abundance, and carbon dioxide, because of the comparative ease with which it can be secured, have been most used in the past. In liquid form, carbon dioxide has been utilized for several years in fire extinguishers. More recently in solid form —commercially known as dry ice—it has likewise been put to fire-fighting service. In both cases, it produces its results by keeping oxygen away from the flames and suffocating them.

Nitrogen also fulfills the function of preventing combustion in an application that is familiar to everyone, although few persons are probably aware of it. We refer to its use in incandescent bulbs. In order to prevent oxidation, or burning out of the filaments, it was the practice completely to evacuate the globes. But this proved expensive and, likewise, only partway effective, as traces of oxygen inevitably remained and ultimately caused failure of the filaments. The problem was solved by filling the bulbs with nitrogen after they had been evacuated.

The application of inert gases to industrial fire protection seems to have originated in Germany in 1905, when Martini and Huneke devised a system of introducing carbon dioxide from flasks into the spaces above flammable liquids for the purpose of preventing the formation of explosive vapor-air mixtures. Within a few years the method had been applied to the protection of volatile fluids in dry-cleaning plants, rubber and paint factories, and to gasoline tanks in the automobile industry and at delivery stations. From that beginning, it spread to other countries.

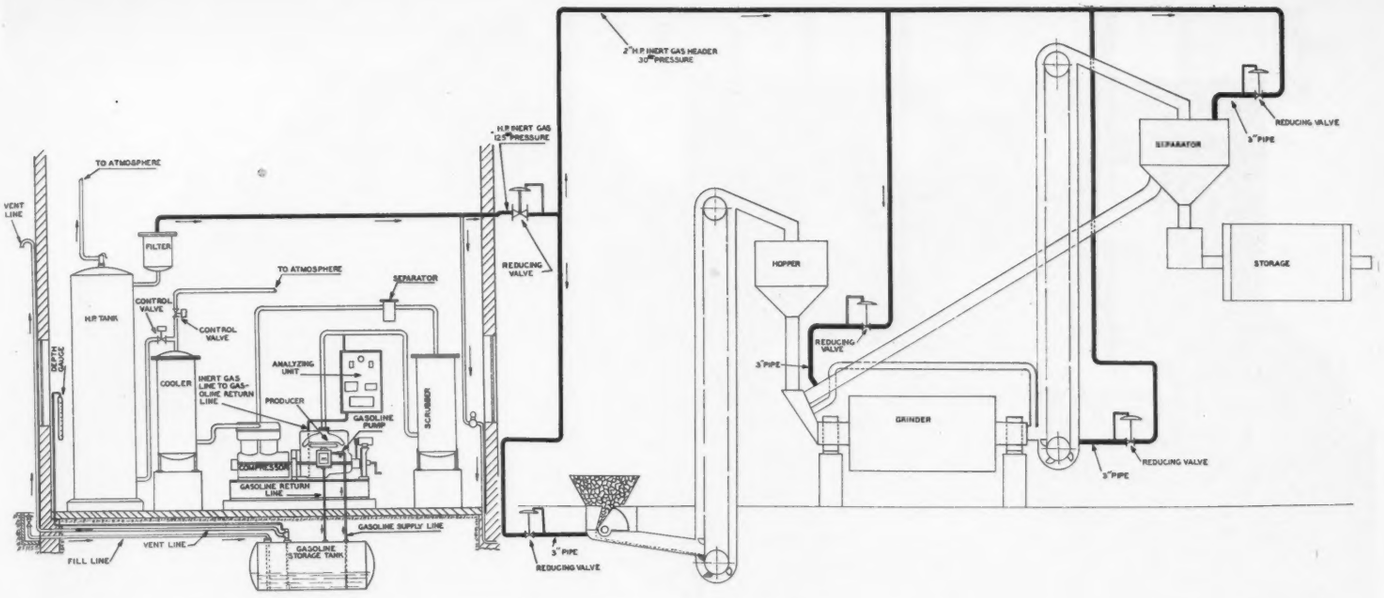
Where relatively small quantities of inert gas were required, the usual custom was to employ carbon dioxide because it was readily obtainable in steel containers which were easily handled. With increasing volume, the cost rose, and efforts were turned towards developing less expensive gases. The present trend is towards a combination of nitrogen and carbon dioxide. Not only are there various sources of such a mixture, but it is also more satisfactory than carbon dioxide, alone, as its specific gravity is more nearly that of the normal atmosphere. Carbon dioxide is heavier than air, and there is always the chance that it will settle out of the air with which it is mixed in the space above a flammable fluid and thus permit the air to combine with the vapor to form an explosive mixture at the top of the inclosure.

A mixture of approximately 84 per cent nitrogen and 16 per cent carbon dioxide can be obtained from the complete combustion of oil, gas, or coal. The nitrogen is contained in the original air that contributes to the combustion: the carbon dioxide is formed by the union of the oxygen in the air and the carbon from the material being burned. Two methods of securing this inert gas have been principally used in the past: the burning of either oil or illuminating gas in a special inert-gas-producing furnace and the collecting of flue gases from boiler stacks. In both these cases it is difficult or impossible to obtain the complete combustion that is necessary to yield a gas devoid of oxygen, the percentage of which



TRANSFERRING LIQUID FROM A TANK CAR

Inert gas under sufficient pressure to start a siphoning action is piped into the top of the car. The storage tank which is to be filled is first charged with inert gas; and, as the liquid enters it, this gas is displaced and flows to the space being left in the tank car as the liquid leaves it. Fusible plugs on the connections at the car will melt in case of fire, stop the flow, and suffocate the flames. A twin pipe connection in the pit is so designed that it is impossible to hook the lines up wrong. A fusible plug from a high-pressure inert-gas line furnishes protection against fire in the pit.



TYPICAL INSTALLATION FOR A GRINDING MILL

Diagrammatic layout of a protective system for a chemical company to safeguard the grinding of highly flammable resins. The heavy black lines show the course of the gas which protects the grinding, elevating, and separating operations by maintaining an atmosphere too low in oxygen content to support combustion. Note that the gasoline storage tank for the engine is also safeguarded.

may range from 2 to 8 per cent in the first product and from 8 to 13 per cent in the second. Accordingly, while gases derived in these ways are suitable for many fire-protection purposes, they do not give the positive assurance of safety which is desirable where flammable substances are being handled.

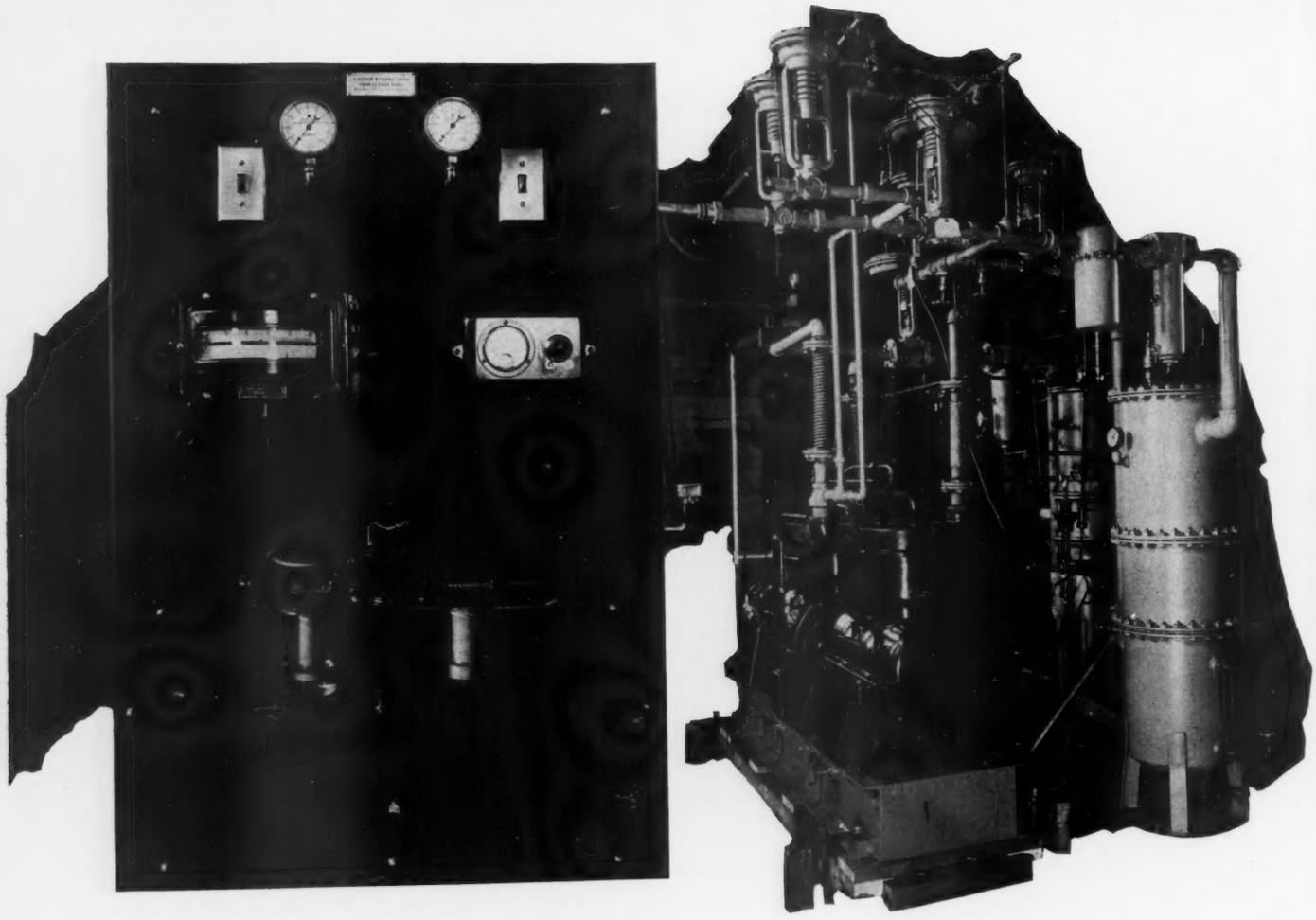
The most satisfactory method of producing a gas of extremely low oxygen content is by burning gasoline in an internal-combustion engine. This process was first applied in Germany, and has since been improved in this country to the point where it now yields the most effective inert gas obtainable and makes it available at a cost lower than that of any of the other products of comparable safety. Apparatus designed especially for this purpose are manufactured by the United States Fire Protection Corporation, of Hoboken, N. J.—the only corporation whose equipment has been passed and listed by the Underwriters' Laboratories and the Associated Factory Mutuals. One of the most important of these, which are covered by recent patents, is a device that automatically and continuously indicates the amount of carbon dioxide in the gas being produced and that controls the supply of this gas for plant use. This instrument furnishes a positive check on the composition of the gas, including its oxygen content, and rejects to the atmosphere any gas that is not of proper composition. The sample gas going through the analyzer comes direct from the engine-exhaust line and is cooled in a separate cooler before reaching the analyzer.

The gas-producing equipment consists of a gasoline-engine-driven compressor and the necessary accessories. From an economical standpoint, such an arrangement is exceedingly effective, inasmuch as it is possible to use the power produced through combustion to drive the compressor, which reduces the volume of the gas for storage. Officials of the company state that they can produce and compress inert gas for as little as 20 cents per 1,000 cubic feet, which compares with a cost of from $5 to $10 for a like quantity of carbon-dioxide gas delivered in bottled form. One gallon of gasoline will produce 1,200 cubic feet of inert gas and at the same time furnish the power to compress it. The equipment is designed for installation on the premises where the gas is used. Where the demand for the gas is great enough, the apparatus is operated continuously: where it is less, intermittent operation and storage in receivers suffice. Units are built in a number of sizes for capacities of from 1,000 to 36,000 and more cubic feet per hour.

To secure a gas of unvarying composition, it is necessary to maintain constant operating conditions. The temperature and pressure within the engine cylinders and the speed of the engine must be the same at all times. Automatic features of the equipment insure that these requirements will be fulfilled. When the producer and compressor are started, the compressed gas is discharged to the atmosphere until the engine reaches an effective speed and until the temperature within the engine cylinders is high enough to insure complete combustion of the gasoline. When the desired heat in the cylinders is reached, that fact is made evident by the temperature of the cooling water, which passes first through the compressor and then goes to the engine. A thermostat on this water line automatically closes the discharge to the atmosphere when the predetermined temperature is reached. The gas exhausted from the engine passes through a scrubber to remove impurities and through an oil-and-water separator before going to the compressor intake. This low-pressure system is maintained under a pressure of about ½ pound to the square inch by bleeding back to it through a reducing valve a small portion of the compressed gas. This pressure is kept constant by means of a pressure-retaining valve which prevents it from dropping and by a manometer-controlled blow-off valve which opens and discharges the gas to the atmosphere if the pressure gets too high. The holding of this low-pressure system at a pressure above atmospheric guards against air entering the system even if a leak occurs and also exerts back pressure against the engine exhaust and thereby keeps the engine operating conditions uniform.

The gas is compressed to 105 pounds gauge pressure, and is discharged into a storage tank. Before going to storage, however, it passes through an afterscrubber to be cooled. Pressure-retaining valves keep the discharge pressure constant and insure that the engine will always operate against a constant load. A special carburetor is provided to regulate the air-gas mixture so as to secure as nearly complete combustion as possible and thereby keep the oxygen content of the exhaust gas at a minimum. If combustion is perfect, the gasoline-engine exhaust gas will consist of about 86.5 per cent nitrogen and 13.5 per cent carbon dioxide. Under actual operating conditions, a trace of either carbon monoxide or oxygen will be present. Either can be excluded, but not both.

The carbon-dioxide analyzer is of the thermal-conductivity type—the difference in thermal conductivity between two cells being indicated on a contact galvanometer. It is a variation of a standard device, is dependable, and measures carbon dioxide in a gas mixture regardless of the combinations of other gases that the mixture might contain. This indication at all times checks with an Orsat reading of the gas.



GAS PRODUCER, AND CARBON-DIOXIDE ANALYZER

Before being installed, each inert-gas producer is set up in the shop of the manufacturer and given a complete test. The equipment at the right, which was designed for safeguarding the grinding of flammable resins in an industrial plant, was photographed while on test.

The panel shown above contains the carbon-dioxide analyzer which might be termed the heart of the system. A continuous sample of the gas is passed through the apparatus at the lower part of the board. It is divided into two streams; the carbon dioxide is chemically removed from one; and then is measured the difference between the cooling effects as exerted by the two streams upon electrically heated platinum coils. Registered on a properly calibrated galvanometer, this indicates the percentage of carbon dioxide, which, in turn, governs the oxygen content. Whenever the carbon dioxide falls below the limit set, the gas is automatically discharged to the atmosphere instead of flowing to the storage tank. The board shows a white light when the gas is satisfactory and a red one when it is unsatisfactory.

The United States Fire Protection Corporation, though only incorporated in 1929, has developed the present equipment to satisfy the demands for protection. For seventeen years it has been active in the field of fire prevention; but in that time has mainly confined itself to work for the United States Government. The Navy Department is now discussing with the company the design of apparatus for fire protection and prevention to be installed aboard ships to be built under our current naval program. By utilizing the equipment it is feasible to maintain a definite percentage of inertness in a compartment so as to protect it against spontaneous combustion and at the same time keep the oxygen content high enough to permit human beings periodically to enter it without ill effects.

This system has already been applied in numerous ways, and there are many other possible uses for it. Thus far it has been adopted principally by concerns that use acetone, carbon bi-sulphide, and similar highly volatile fluids in their manufacturing processes. It is also being used to safeguard explosive dusts resulting from grinding operations in various industries. Accompanying illustrations show typical installations, and indicate how the protection is extended to the several stages of individual processes.

It will be noted that where the gas is used to protect bulk storage of liquids, it is also employed as the pumping medium for filling the tanks and for withdrawing fluid from them. This is done by admitting the gas, under pressure, to the top of the container and forcing the liquid out through piping extending to the bottom. Double delivery piping is used; and the annular space around the inner one is blanketed with inert gas to prevent the admittance of air in case of a leak. Should the outer piping break, or develop a leak, the gas will escape and, by relieving the pressure on top of the liquid, stop pumping. The liquid in the piping system will then drain back into the tank. Escape of the inert gas and vapors from the tank is prevented by antidiffusing valves.

Inert gas is being extensively used as a substitute for compressed air in agitating flammable liquids, and it has been already applied in this manner in some plants. In certain lines of manufacture, inert gas has been found to have an economical virtue aside from its protective value. When it is used in pebble mills, where paint pigments are ground, it prevents oxidation and results in a better product and a greater conservation of materials. Similarly, it has been discovered that, if the space remaining in a can of paint after it is filled is blanketed with inert gas instead of air, the gas will eliminate oxidation and prevent the formation of the scum or skin that is familiar to everyone who has ever viewed a freshly opened can of paint.

There are various other fields where inert gas can probably be employed beneficially. One potential use now being investigated is the safeguarding of gas tanks at distributing plants particularly while they are being cleaned.

POLICIES

NUMBER THREE

of A Series of Advertisements Outlining Policies of

COMBUSTION ENGINEERING COMPANY • INC

Numbers One and Two of this series outlined those *sales* and *engineering* policies of Combustion Engineering which have a direct bearing on its relations with customers. This and the succeeding advertisement will cover similar policies with respect to *manufacturing* and *service*.

MANUFACTURING POLICY

Combustion Engineering predicates its manufacturing policy on a major conception of its business which has been stated previously in this series; namely, *that future sales depend primarily on satisfactory installations*. One of the obvious essentials of a satisfactory installation is that the equipment be so manufactured that it can be relied upon to give dependable service. In the case of equipment which is vital to the basic processes of steam and power generation, the importance of the factor of *dependableness* is self-evident.

Another essential of a satisfactory installation is that the equipment be so constructed as to assure minimum maintenance costs, not merely for a year or two but throughout its reasonable lifetime.

These considerations make apparent the logic and commercial soundness of Combustion Engineering's manufacturing policy which, briefly stated, is to turn out the best work which *exacting standards, well trained workmen, complete and modern equipment, the use of the best materials* and *adequate inspection and testing facilities* will permit.

It is one thing to state such a policy; it is quite another to be able to carry it out. Combustion Engineering has not only the purpose but also the facilities to do so.

Its manufacturing plant at Monongahela, Pa., is second to none of its class in the country. This applies to all its departments,—foundry, pattern shop, machine shop, sheet metal shop, etc. The automatic welding department at Monongahela is one of the most completely equipped of its kind. The products manufactured at this plant include all types of stokers, pulverized fuel burners, feeders, etc., air preheaters, water-wall tubes and miscellaneous castings.

The company's boiler shops at Chattanooga, Tenn., are known for the completeness and excellence of their facilities,—foundry and pattern shops, plate shop, sheet metal shop, machine shop and forge shop. Particularly notable at this plant are the specially-designed annealing furnace used in connection with welded drums and pressure vessels, the X-ray testing facilities for welded vessels and the metallurgical laboratory which is fully equipped to handle any research or test problems on base metals or alloys.

The company's plant at Chicago is fully equipped for its specialized work of manufacturing Raymond pulverizers and milling equipment.

These manufacturing facilities permit the complete fabrication and testing of Combustion Engineering equipment under full control at all times, thus assuring the company's ability to carry out its policy.

COMBUSTION ENGINEERING PRODUCTS

•

BOILERS

C-E Sectional Header Boiler
C-E Box Header Boilers
C-E Bent Tube Boilers
C-E H.R.T. Boilers
C-E Electric Boilers

STOKERS

C-E Multiple Retort Stoker
Type E Underfeed Stoker
Type E Stoker-Unit (*for small boilers*)
Type H Stoker (*for industrial furnaces*)
Coxe Traveling Grate Stoker
Green Chain Grate Stoker (*natural draft*)
Green Chain Grate Stoker (*forced draft*)

PULVERIZED FUEL

Lopulco Storage System
Lopulco Direct-Fired System
Raymond Pulverizing Mills

WATER-COOLED FURNACES

C-E Water-Cooled Furnace
Lopulco Water Screen
C-E Slagging Furnace

COMPLETE UNITS

Coordinated designs comprising any combination of boiler and firing equipment and
Combustion Steam Generator
(*a standard unit for medium-sized and large plants*)
C-E Steam Generator Unit
(*a standard unit for small plants*)

OTHER EQUIPMENT

C-E Air Preheaters
(*plate and tubular types*)
C-E Economizer
Quinn Oil Burners
Grieve Grates
C-E Ash Conveyors
C-E Ash Hopper

NRA MEMBER U.S. WE DO OUR PART

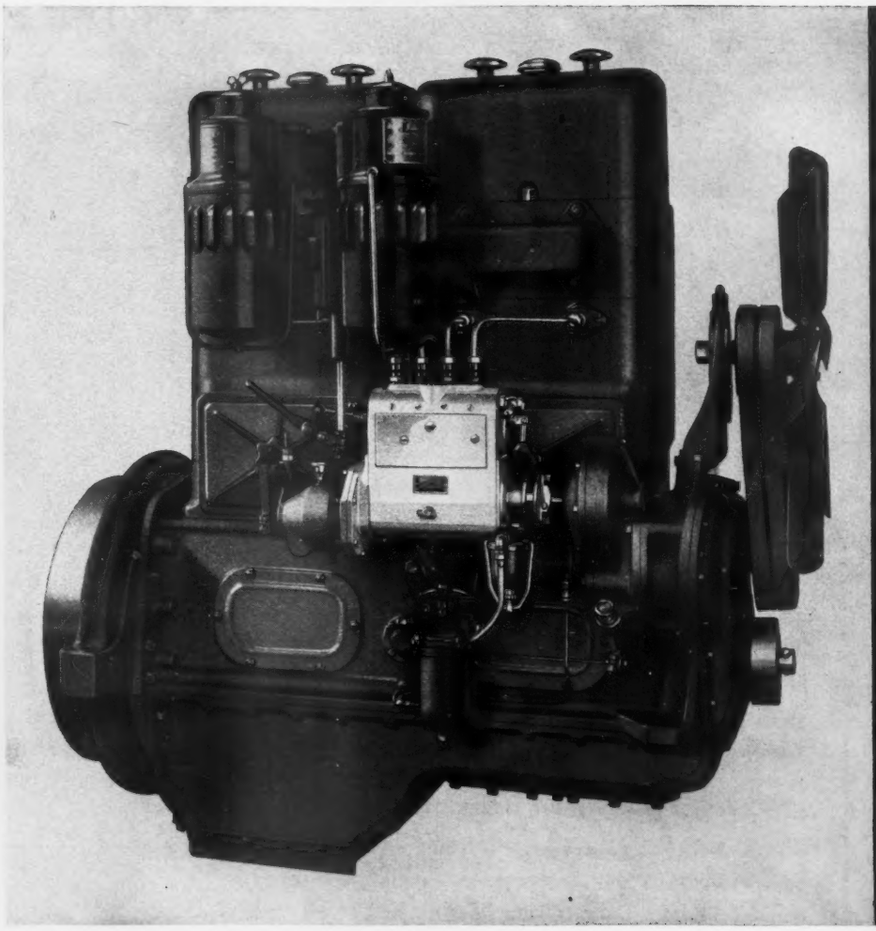
COMBUSTION ENGINEERING COMPANY • INC

200 MADISON AVENUE, NEW YORK • OFFICES IN PRINCIPAL CITIES

Canadian Associates, Combustion Engineering Corporation, Ltd., Montreal

A-107a

WAUKESHA-HESSELMAN OIL ENGINE



BURNS CHEAP FUELS

•

Not at all fussy about its fuel—this Waukesha-Hesselman Oil Engine. Any fuel a Diesel will handle . . . some that a Diesel can't . . . even alcohol and gasoline mixtures without change in its adjustments. And it doesn't smoke.

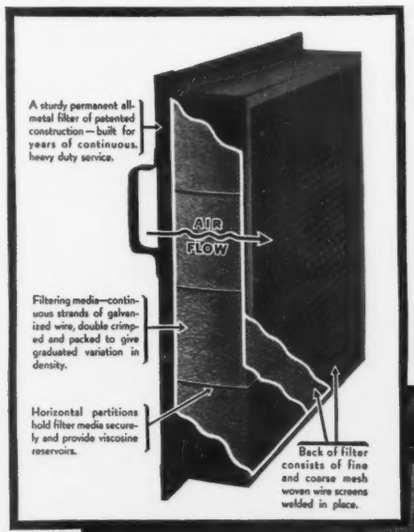
• A 40 hp. Hesselman can show an economy the equivalent of 14 hp-hr. per gallon of fuel oil. At today's prices for heavy fuel oil, this is economy.

• A Hesselman starts just as easily as a gasoline engine . . . hand cranking is just as practical and with electric ignition, starting is just as certain. Operation is exactly as smooth . . . at all speeds. Upkeep is just as low. Simple in construction . . . anyone understanding gasoline engines can operate it.

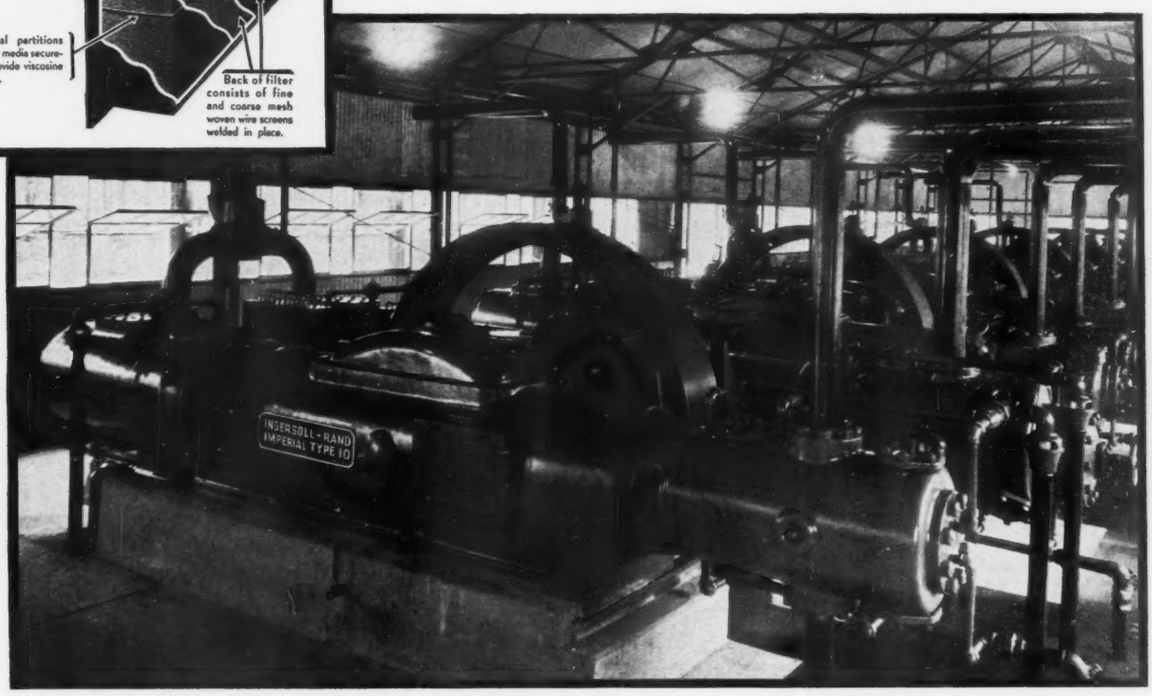
• Waukesha-Hesselman Engines range in size from 3¾ in. x 4¾ in., 4 cylinders, to 6½ in. x 8 in., 4 cylinders; from 25 hp. to 110 hp. Write for Bulletin 894, Waukesha Motor Company, Waukesha, Wisconsin.

WAUKESHA ENGINES

The CHIEF ENGINEER *of* INGERSOLL-RAND CO. *Says*


A sturdy permanent all-metal filter of patented construction—built for years of continuous, heavy duty service.
AIR FLOW
Filtering media—continuous strands of galvanized wire, double crimped and packed to give graduated variation in density.
Horizontal partitions hold filter media securely and provide viscosine reservoirs.
Back of filter consists of fine and coarse mesh woven wire screens welded in place.

"We would like to see All Air Compressors *and* Diesels Equipped *with* AIR FILTERS"



Experienced engineers appreciate the value of clean air. They know that dust and grit are responsible for high operating costs, excessive oil consumption and expensive replacements and repairs.

Engineers familiar with air cleaning equipment prefer American Viscous Type Air Filters because, when their high cleaning efficiency and low maintenance cost are considered, they are by far the most economical.

Hundreds of American Air Filters, viscous type, are protecting diesels and compressors against dust and grit and have been for years. Their only upkeep costs consist of periodical cleaning using regular plant maintenance labor and $1.00 per year or less per thousand C.F.M. for viscous charging liquid.

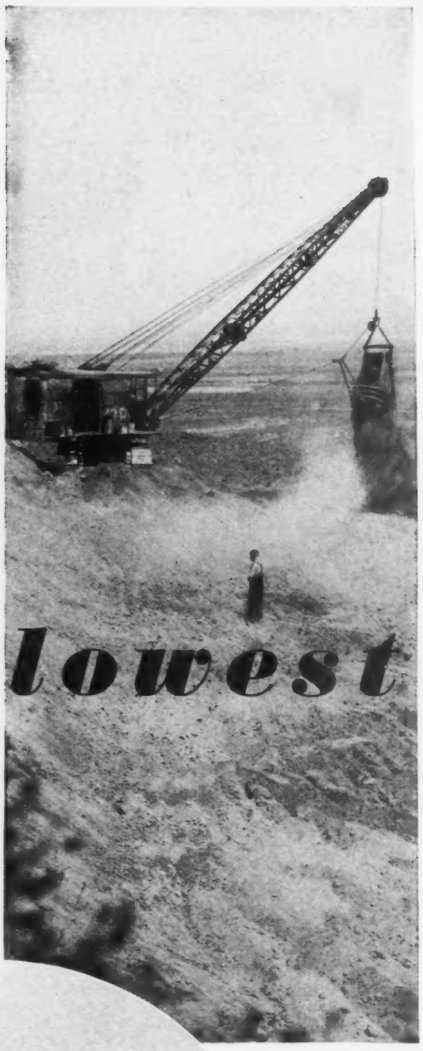
The American Air Filter Company is the world's largest exclusive manufacturer of air filters. Our staff of experienced engineers is always at your disposal. Send for complete literature and prices without obligation to you.

NRA MEMBER U.S. WE DO OUR PART

AMERICAN AIR FILTER COMPANY, *Inc.*
114 Central Avenue **Louisville, Kentucky**
In Canada, DARLING BROTHERS, LIMITED, Montreal, P. Q.

AMERICAN AIR FILTERS

YOU NEED Balanced VALUE *to get lowest costs!*



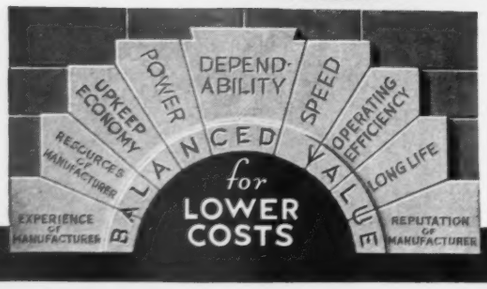
When you buy an excavator you want a unit that will give you lowest possible output cost. This can be secured only by buying the machine that gives you the most in balanced value.

One or two outstanding features may contribute to lower costs, but any advantage they can give is very easily offset by lack of balance in other essentials.

Dependability, power, speed, operating efficiency, long-life, upkeep economy, manufacturer's resources, experience and reputation . . . it takes them all to move dirt profitably throughout the lifetime of the machine.

Compare the excavators you consider with the balanced value offered in the desired size from the Bucyrus-Erie complete line.

BUCYRUS-ERIE COMPANY
South Milwaukee, Wis.

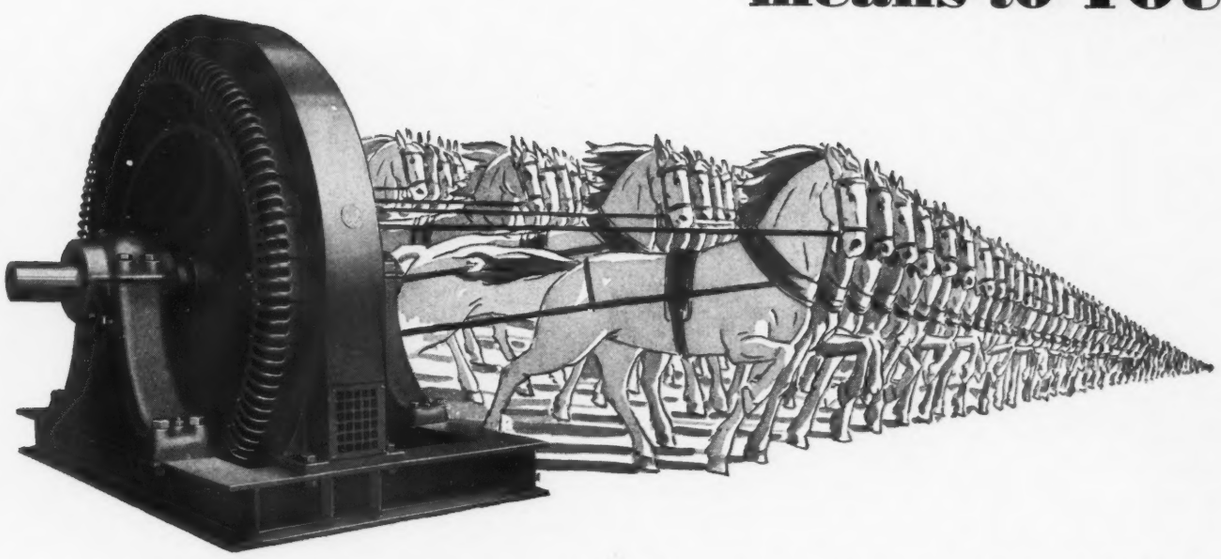


All sizes: ½- to 20-yards . . . shovels; draglines; dragshovels; skimmer scoops; cranes; clamshells; dredges; tower excavators; tunnel shovels; Bucyrus-Monighan walking draglines . . . gasoline, Diesel, electric, Gas+Air, Diesel-electric, and steam powered . . . railway cranes; spreader plows; ballast plows; Loadmaster cranes; Red Arch dragline buckets; Bucyrus-Armstrong blast hole drills, well drills, tools and drill sharpeners.

633

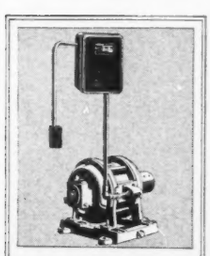
See BUCYRUS ERIE *before you buy!*

What 6,000,000 Hp.
of G-E synchronous motors means to YOU



It means that General Electric, in producing 6,000,000 hp. of synchronous motors, has acquired extensive experience and has developed a great variety of these motors.

G-E synchronous motors and control are part of the complete G-E line that assures you the RIGHT MOTOR and the RIGHT CONTROL for your specific application. Thus, when a synchronous motor is the best motor for your requirements, General Electric can provide the right one.



THE RIGHT MOTOR
THE RIGHT CONTROL
FOR EVERY APPLICATION

Why not investigate the advantages of the synchronous motor as a constant-speed drive? Our new 52-page bulletin will help you in such an investigation. This coupon will bring you a copy.

NRA
WE DO OUR PART

GENERAL ELECTRIC

MAIL THIS COUPON NOW

General Electric Company, Dept. 6G-201
Schenectady, New York

Please send me a copy of your new bulletin, "Synchronous Motors," GEA-1191A.

Name.....

Firm.....

Address.....

107-92

WORLD-WIDE . . . AND IN YOUR PLANT

A Vital Cog

in cost control

Today, labor costs are higher! Raw material costs are higher! Selling costs are higher! Now is the time to profit by the experience of world-wide plants in every industry and let Gargoyle Lubricants help reduce your major *plant* costs.

For, in your plant, too — Gargoyle Lubricants can reduce power costs 3% to 10%. They can lower your maintenance and repair expense. They may help speed up your production schedules. They'll certainly insure you against machinery shutdowns.

The cost of lubrication is a trifling one — probably less than 1% of your total costs of conversion. Yet this seemingly insignificant item controls major costs in your plant. Plant records, written in every language, prove that Gargoyle Lubricants *can easily save you many times your total annual cost of oil.*

Any Socony-Vacuum representative will be glad to show you lower-cost records made by leading plants in your own industry . . . to suggest means by which you can lower today's costs in *your* plant.

Socony-Vacuum Corporation, 26 Broadway, New York City. Branches and distributors throughout the world.

SOCONY-VACUUM
CORPORATION

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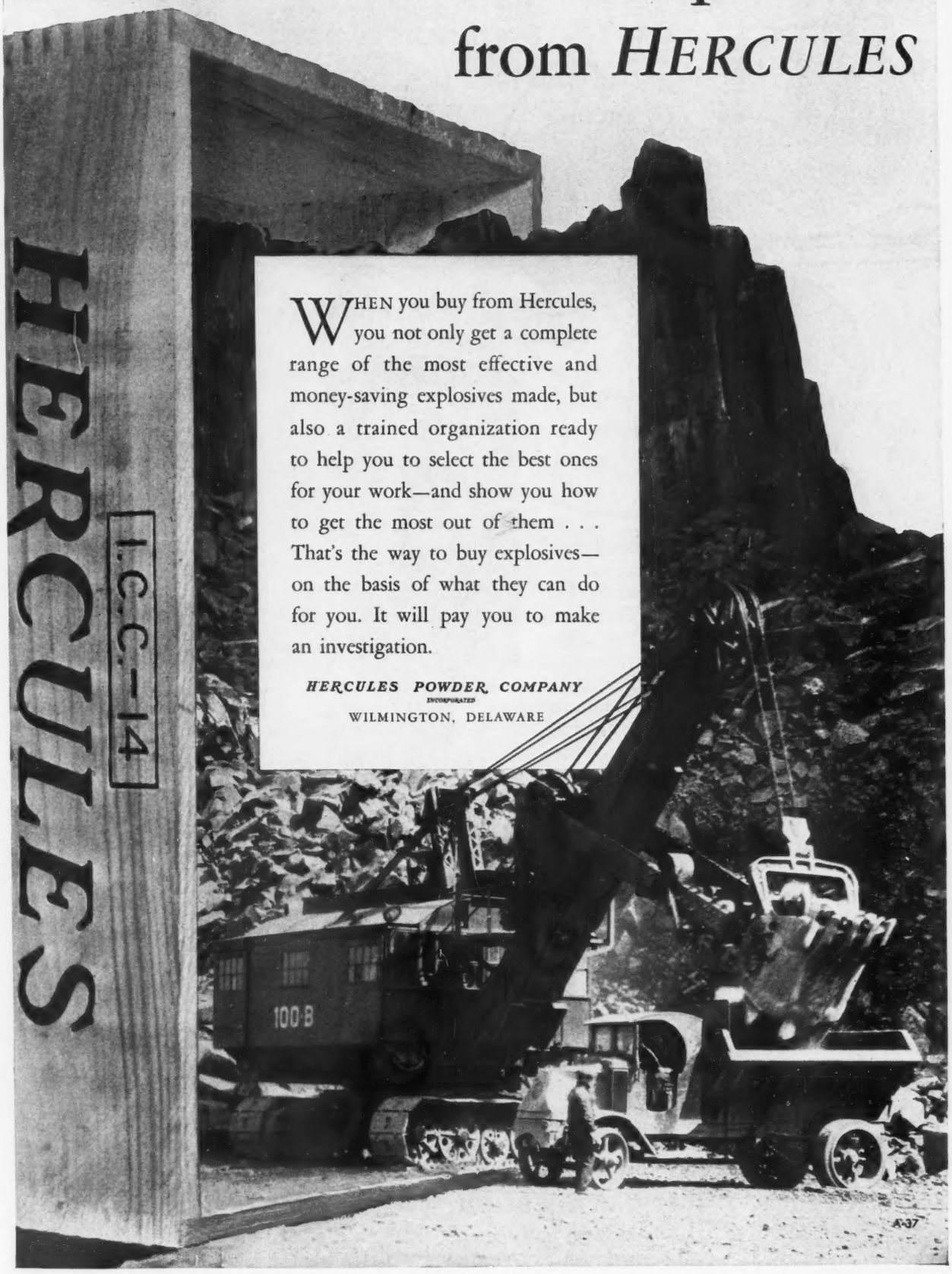
You Get *More Than* Explosives from *HERCULES*

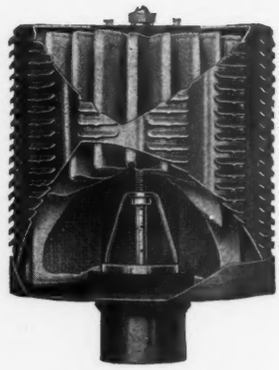


WHEN you buy from Hercules, you not only get a complete range of the most effective and money-saving explosives made, but also a trained organization ready to help you to select the best ones for your work—and show you how to get the most out of them . . . That's the way to buy explosives—on the basis of what they can do for you. It will pay you to make an investigation.

HERCULES POWDER COMPANY
INCORPORATED
WILMINGTON, DELAWARE

Cleaning the air reduces the wear

Pipe Line Filter



Protectomotor Air Filter

Eliminates 99-9/10% of dust and dirt from air delivered to machines. Reduces wear 75 to 85%. Cuts carbon deposits 60 to 70%. Saves oil. Muffles noise. Makes compressors, Diesel engines, etc. operate from 3 to 5 times longer before overhauling is necessary.

Pipe-line filtration is a definite and constant source of revenue. Compressed air drills, riveters, and other pneumatic tools wear longer and do better work. Sprayers deliver cleaner, purer paint with less danger of the fine spray nozzle becoming clogged by foreign matter. Anywhere that power lines from a central pressure tank are used, Protectomotor Filters in the pipe lines, as well as on the air intake of the compressor itself, will more than pay for themselves in the depreciation and grief they prevent.

Removing oil, water, dirt, rust, scale, and all other foreign substances from the air passing through the lines, they deliver air cool and dry.

The Protectomotor Pipe Line Filter consists of a felt filter element formed on a fine-wire screen shaped in fins, in an aluminum housing encased in a pressed steel shell with flanged joint made to withstand a working pressure of 125 lbs. Higher pressure shells can also be supplied as special equipment.

Settlings of water, oil, and sediment are withdrawn through a pet-cock, and by closing a valve to shut off air going into the filter housing, and opening the drain-cock, the air in the outlet pipes or hose blows back through the positive filter element, removing all accumulations.

PROTECTOMOTOR
REG. U.S. PAT. OFF.
99 9/10 Per Cent EFFICIENT
AIR FILTERS

Write for booklet and information on our 30 day FREE TRIAL OFFER.

Staynew Filter Corporation
7 Leighton Ave., Rochester, N. Y.

STAYNEW FILTER CORPORATION
7 Leighton Ave.
Rochester, New York

Please send copy of your catalog on Protectomotor Air Filters for use on .....

.....

Name .....

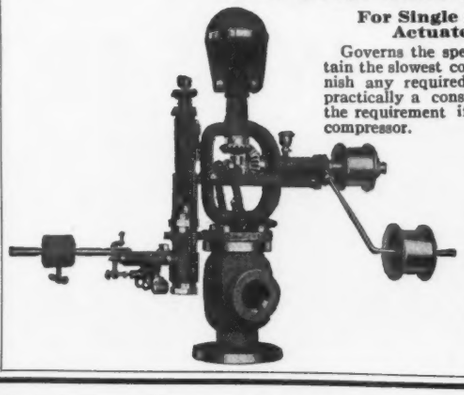
Address .....

Town ..... State .....

ERIE COMPRESSOR GOVERNOR

For Single and Duplex Steam Actuated Compressors

Governs the speed of Compressors to maintain the slowest constant speed which will furnish any required supply and will maintain practically a constant air pressure, whatever the requirement if within the capacity of the compressor.



ERIE UNLOADER

NEW STYLE

For Single, Duplex and Multiple Stage Steam, Belt or Electric Driven Air Compressors

Maintains practically a constant air pressure, whatever the requirements. Completely unloads and loads Compressor without shock or strain.

Complete Catalog Upon Request

Jarecki

MANUFACTURING COMPANY

Erie, Pa., U. S. A.

PRINTED IN U.S.A.

COMPRESSED AIR MAGAZINE

—Founded 1896—

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R. A. LUNDELL, *Vice-President*
F. E. KUTZ, *Secretary-Treasurer*
J. F. KENNEY, *Business Manager*

Business, Editorial and Publication Office: Phillipsburg, N. J.

Advertising Offices:
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Annual subscription rate: Domestic, $3; foreign, $3.50; single copies, 35 cents.

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DIVIDE COMBINATION AIR SEPARATOR AND TRAP

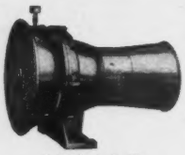
FOR REMOVING OIL AND WATER FROM COMPRESSED AIR

30 years experience in designing separators and traps.
Separators very efficient and traps dependable. Results guaranteed.
We also make Steam and Oil Separators, all sizes and styles.
Largest yet made, 25,000 lbs. in weight, smallest 25 lbs.

Send us your problems.

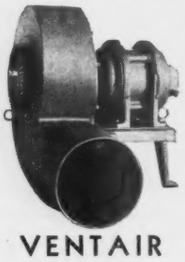
The Direct Separator Co., Inc., - - Syracuse, N. Y.

for DEPENDABLE *and* EFFICIENT *Mine Ventilation-*



VANO

Propeller Type—Medium Pressure—Large Volume Fan



VENTAIR

Centrifugal Type High Pressure Blower

it will pay you to get the facts on Coppus Blowers.

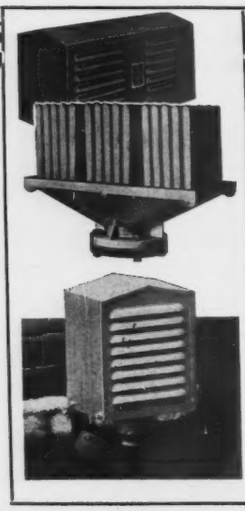
With prices of non-ferrous metals more favorable than they have been for a long time, it is nothing more than good business policy to check over your ventilating equipment, and replace all obsolete and inefficient blowers with Coppus Equipment—if you would insure uninterrupted ventilation. Compressed air or electric motor drive.

Write for full information on—

COPPUS

MINE BLOWERS

for LONGER *and* MORE EFFICIENT *Compressor Life-*



all dust and dirt particles should be removed from the air that is drawn into the cylinders of your compressors and engines.

Annis Air Filters will remove dirt particles 100%—and thereby cut maintenance costs, reduce delays, save on oil bills, and maintain original power and capacity of machine.

It will be worth your while to write for full details on

ANNIS

AIR FILTERS

COPPUS ENGINEERING CORP.

370 PARK AVENUE WORCESTER, MASS.

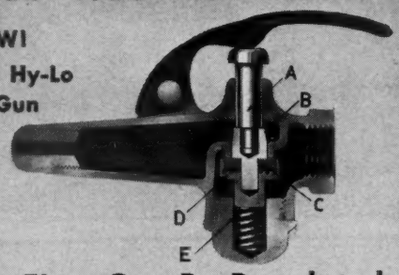
MANUFACTURERS OF

STEAM TURBINES - FORCED DRAFT BLOWERS - HEAT KILLERS - MANHOLE VENTILATORS - TANK EXHAUSTERS - TURBO BLOWERS -

STOPS AIR WASTE

Can't Leak When Closed

NEW! Jenkins Hy-Lo Air Gun



Air Flow Can Be Regulated

In a month, a 1/16" opening in a line at 100 lbs. pressure will waste 278,700 cu. ft. of air. Or $27.87 worth at 10 cents per 1000 cu. ft. . . . enough to pay for several Jenkins Hy-Lo Guns, fitted with a Jenkins Renewable Disc that keeps the seat air-tight, without regrinding. Also having a unique air flow control which permits an operator to regulate the flow to a job. Get Hy-Lo Guns from your supply house. Lever or push button control; round, flat or extension tips.

JENKINS BROS., New York, Phila., Chicago, Boston, Bridgeport, Conn. JENKINS BROS., Ltd. Montreal, London.

How It Works

As spindle (A) is pressed, air volume is increased by throttling lip (B) until wide open. Closing is automatic.. The rim of the seating face of Jenkins Disc (C) is protected by disc holder (D). Air pressure and spring (E) hold disc firmly against seat.

Jenkins

BRONZE IRON STEEL

VALVES

Since 1864

RUEMELIN

Compressed Air Dryers

Extracts all the moisture and oil in the Compressed Air Supply. *"GETS RID"* of operating troubles and wear in all pneumatic equipment.

Highest efficiency.
Costs nothing to operate.
No moving parts to wear out.

Moderately priced.

Sent on 30 day trial. Satisfactory results guaranteed.

Sizes up to 300 cu. ft.

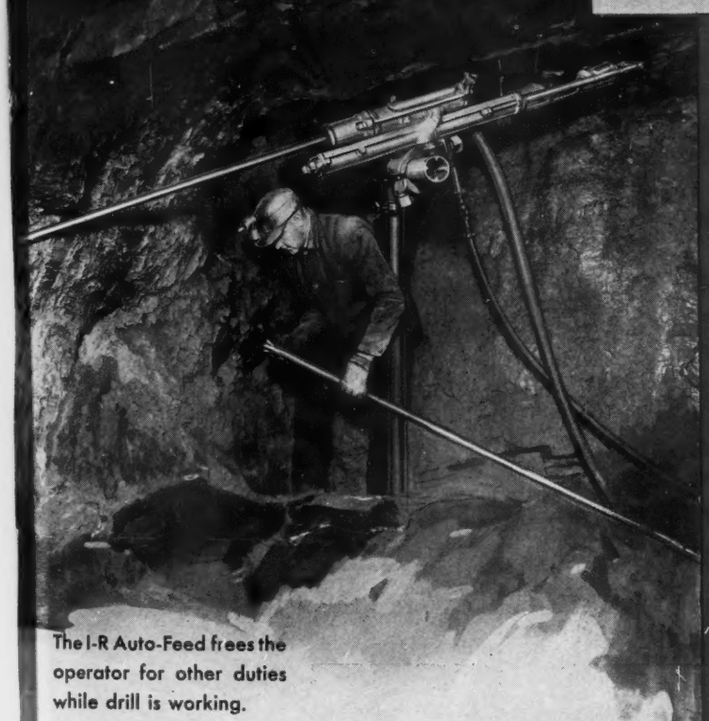
(Patented & Pat. Apld).

AGENTS: Some good territories open.

RUEMELIN MFG. CO.

1580 S. First St., Milwaukee, Wis.
(Mfr's Sand Blast and Dust Collectors)

21 NEW MONEY-SAVING DEVICES *by* INGERSOLL-RAND



The I-R Auto-Feed frees the operator for other duties while drill is working.

THE machines illustrated and described on the following pages have been developed during the past few years in response to the universal demand for lower operating costs. In every case they will be found to afford valuable aid in cutting unit production costs.

More than ever before, however, careful consideration must be given to selecting the right machine for the job. Our technical and service departments have accumulated a wealth of data on mining conditions all over the world, which will gladly be placed at your disposal without charge. Consult our nearest branch office freely—especially on problems which may involve a choice between different types of Ingersoll-Rand equipment.

A New Automatic-Feed Drifter

•

A New "Stopehamer" for hard-rock drilling

•

A New "Jackhamer," adjustable for any kind of rock

•

A New Lightweight Drill Sharpener

•

These and other new money-saving I-R machines are illustrated and described on the two following pages

INGERSOLL-RAND COMPANY, 11 BROADWAY, NEW YORK

BIRMINGHAM	CLEVELAND	EL PASO	NEWARK	PITTSBURGH	SEATTLE
BOSTON	DALLAS	HONOLULU	NEW ORLEANS	PORTLAND	ST. LOUIS
BUFFALO	DETROIT	KNOXVILLE	NEW YORK	SAN FRANCISCO	ST. PAUL
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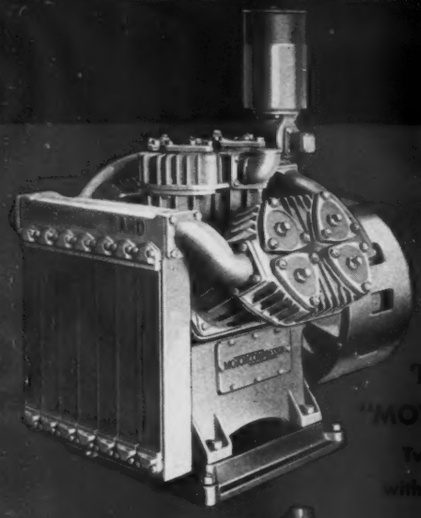
For Canada refer—Canadian Ingersoll-Rand Co., Limited, 620 Cathcart Street, Montreal. Branches or Distributors in principal cities the world over.

London—Paris—Madrid—Vienna—Johannesburg
Calcutta—Tokyo—Lima—Santiago—Buenos Aires
Mexico—Havana—Valparaiso—Rio de Janeiro

These NEW I-R achievements meet money saving machines



5

The "MOTORCOMPRESSOR."
Two-Stage, Air-Cooled with built-in electric motor.

The PORTABLE SUMP PUMP—
air-operated.

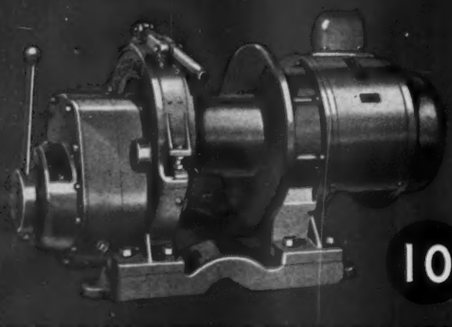
6

7

The "MOTORPUMP"
—operates in any position.

9

SINGLE-DRUM "UTILITY" AIR-HOISTS—
two sizes, capacities 750 to 2,500 pounds pull.



10

SINGLE-DRUM ELECTRIC "TUGGER" HOISTS—

A DRIFTER WITH AUTOMATIC FEED.

1

Increases footage per man shift. Drill feeds forward automatically, maintaining correct contact with the rock while drilling.

The N-79 "STOPEHAMER"
for hard rock—faster and easier to handle.

2

The "JACKBIT"
(detachable)

8

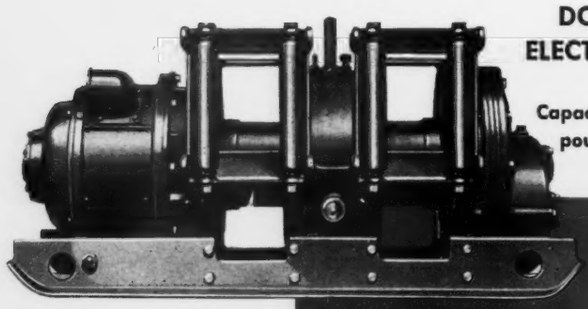
and DRILL RODS
—for more footage.

Ingersoll-Rand presents this new equipment—new in design—new in standards of efficiency—new in the sense of more profitable operation.

Many of the machines are outstanding, but each I-R development merits careful investigation as an aid in reducing production costs.

Bulletins or pamphlets describing any or all of these machines will gladly be sent upon request. The coupon on the next page is for your convenience.

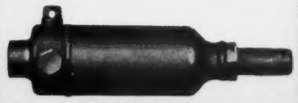
DOUBLE-DRUM ELECTRIC "TUGGER" HOISTS.
Capacities 2,000 to 5,500 pounds pull at various rope speeds.



12

The SELF-PRIMING GATHERING PUMP.

11

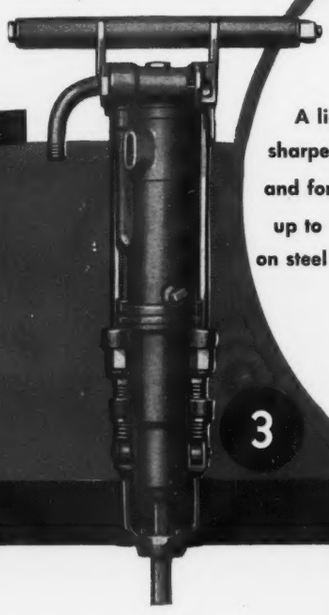


The ADJUSTABLE AIR LINE LUBRICATOR.

14

the present-day demand for in gold and silver mines

The S-68 "JACKHAMER"
— adjustable for efficient work in soft, medium, or hard rock.

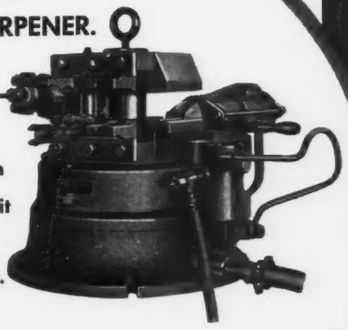


3

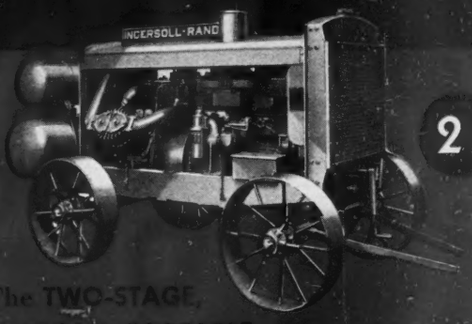
4

The 24 BENCH SHARPENER.

A lightweight drill sharpener that will form and forge any type of bit up to 2½-inch gauge on steel up to 1-inch size.

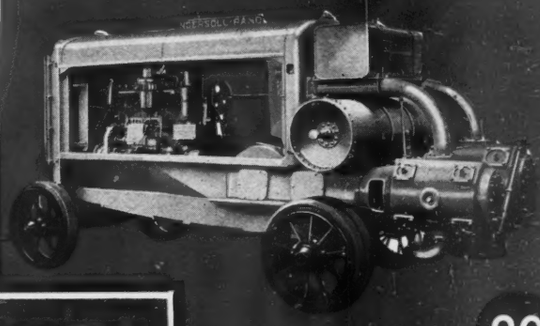


100 per cent air-operated.



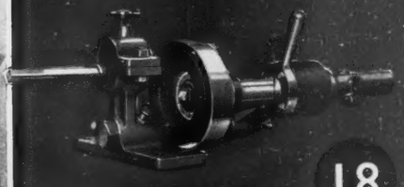
21

The TWO-STAGE, AIR-COOLED PORTABLE—
more air with less gasoline



20

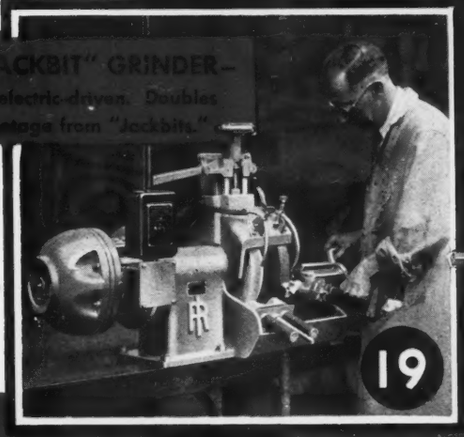
The OIL-ENGINE PORTABLE COMPRESSOR.
Fuel economy plus reliable operation.



18

The SHANK GRINDER—
produces square striking end— reduces drilling costs.

The "JACKBIT" GRINDER—
air or electric-driven. Doubles the footage from "Jackbits."

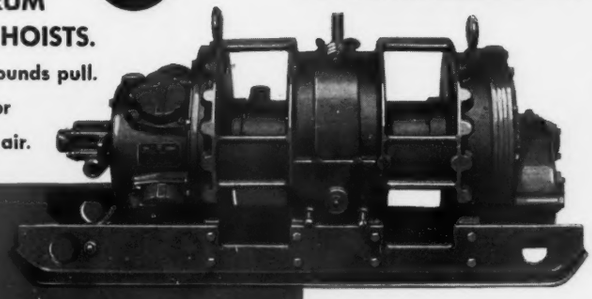


19

The WAGON-MOUNTED DRILL.
Drills faster—
requires less labor—
operator rests while drill works.

17

DOUBLE-DRUM "UTILITY" AIR HOISTS.
Sizes up to 2,000 pounds pull.
One size for low-pressure air.



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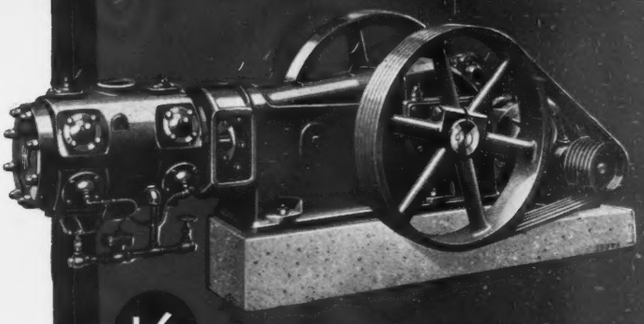
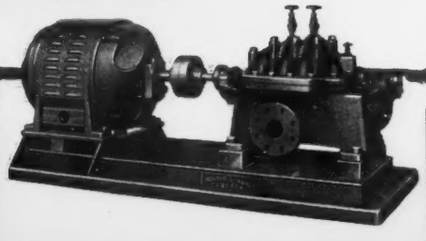


16

ES HEAVY-DUTY AIR COMPRESSOR.
15 to 135 hp.

A complete line of single-stage and multi-stage BALL BEARING PUMPS.



15

INGERSOLL-RAND COMPANY 265-M
11 Broadway, New York, N.Y.

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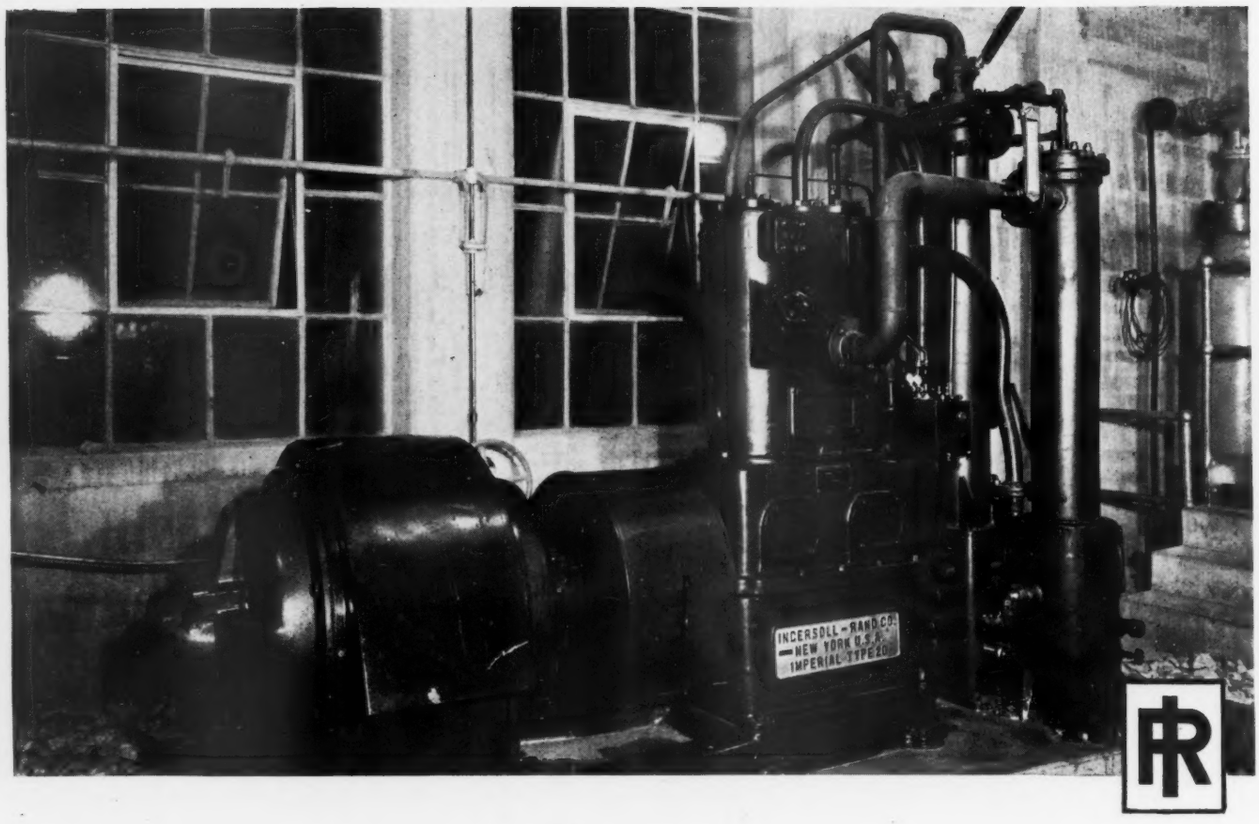

Starting Air for VERNON

ONE of the most important pieces of equipment in the Municipal Light and Power Station, City of Vernon, California, is the three-stage air compressor which supplies starting air for the five main 7000 HP Hamilton-M.A.N. Diesel engines.

A Diesel Engine Plant is no more reliable than its starting air compressor and we are modestly proud of the fact that Ingersoll-Rand was chosen to build this vertical 8″ stroke, four-cylinder, 1000 lb. compressor, which is direct-connected to a 60 HP General Electric motor.

Specially designed for this large plant, this compressor is depended upon day in and day out to maintain starting air for the 35,000 HP Vernon Diesel installation. The whole plant relies on this piece of equipment for its continuous and successful operation.

Ingersoll-Rand builds air starting units to fit plants of any capacity.

1060-C

Ingersoll-Rand

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Rugged

Efficient

Easily Handled

Enormous Capacity

Stiff-Leg Plow Control

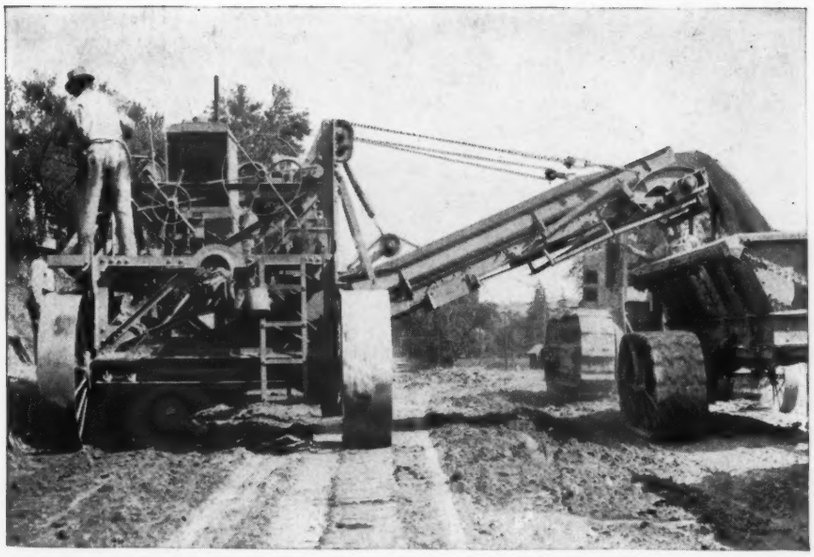
Three Point Suspension

Automatic Belt Control

Tubular Frame

Motor Driven Belt

One Piece Elevator

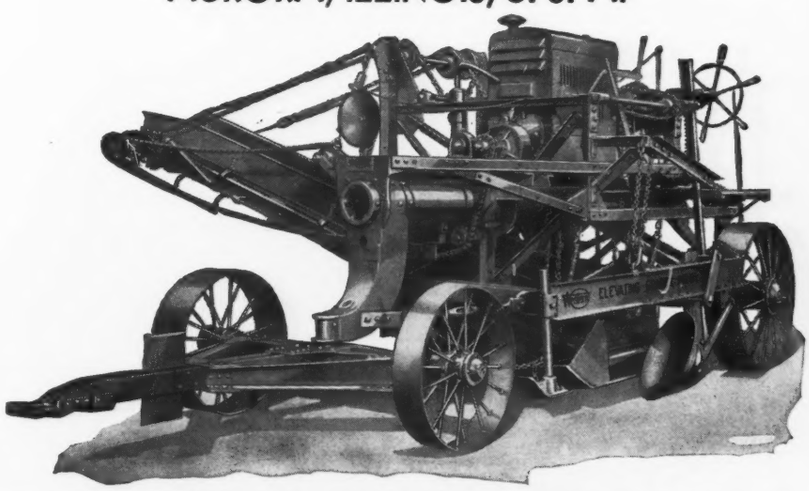


A Western No. 6 Elevating Grader makes short work of loading a Western Crawler Dump Wagon. Notice the stream of dirt falling from the elevator.

Think what these superior features of the Western No. 6 Elevating Grader mean in increased yardage and lower costs. On work to which it is suited, the elevating grader is the most economical machine to use. If you have a stripping job or any other dirt work on which an elevating grader can be used, any other type of equipment is costing you money.

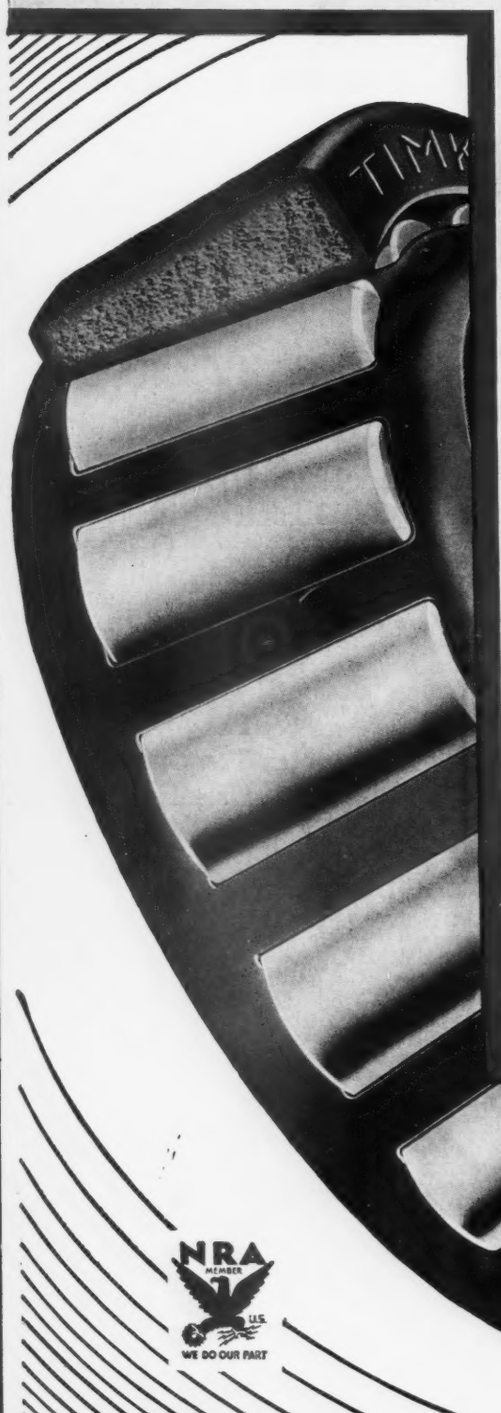
The Western No. 6 is the last word in elevating grader design. It is rugged, efficient, and loads an enormous yardage. The No. 6 operates in all kinds of soil and easily loads material so hard it could not be entered by a loose hung plow. This is but one of the unique features of this machine. Catalog 31-CF fully describes them all. Where shall we send your copy? Write today.

WESTERN WHEELED SCRAPER COMPANY
AURORA, ILLINOIS, U. S. A.



WESTERN

"TIMKEN" SATISFACTORILY ANSWERS EVERY BEARING QUESTION IN ALL TYPES OF MACHINERY



In hundreds of thousands of machines of every type throughout all industry, millions of Timken Tapered Roller Bearings are meeting every operating condition as no other type of bearing could meet them.

There is hardly a single bearing problem that has not been satisfactorily solved with Timken Bearings, including air compressor and engine crank shafts.

This versatility comes from a combination of mechanical features exclusively Timken. These features are:

1—Timken tapered construction which permits the carrying of radial loads, thrust loads or both together in any combination.

2—Timken positive roll alignment which prevents skewing and binding under load.

3—Timken line contact which holds moving parts in correct and constant alignment.

4—Timken-made special alloy steel which assures maximum strength and wear resistance.

5—Timken precision of manufacture which reduces internal friction to the vanishing point.

The same combination will enable your new machines to perform better and last longer. It will pay you to specify—and insist on—Timken Bearing Equipped.

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TIMKEN *Tapered Roller* **BEARINGS**